AUSTRALIAN® MANGOES SCIENTIFIC SYMPOSIUM

connect, inspire, innovate 2024

20 MAY, CAIRNS

1st Australian Mango Scientific Symposium

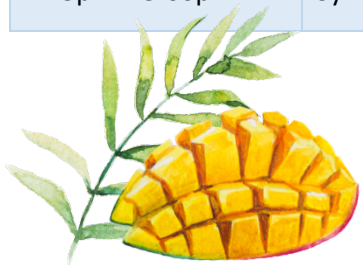
Proceedings

20 May 2024

Cairns Convention Centre

8:30am – 9:00am	Registration	
(M9 & M10) 9:00am – 9:20am	**Introduction** Marine Empson – AMIA Andrew Francey – Hort Innovation	
(M9 & M10) 9:20 – 10:35am	**Breeding, genomics & varieties** MC – Ian Bally (QDAF) ○ Optimisation of selection in the progenies of *Mangifera indica* – Asjad Ali (QDAF) ○ Genome assembly & evolutionary relationships of *Mangifera indica* & related species – Upendra Wijesundara (QAAFI) ○ The development of high efficiency, dwarfing rootstocks for the Australian mango industry – Ryan Orr (QDAF) ○ Using functional genomics approaches to study mango flowering – Stephanie Kerr (QUT) ○ Q & A panel (15 mins)	
10:35am – 11:05am	Morning tea	
11:05am – 12:20pm	**Agronomy** (M9 & M10) MC – Michael Finey (NT DITT) ○ Facilitating industry adoption of intensive mango practices and new ag technologies in Australia – Geoff Dickinson (QDAF) ○ Planting density and canopy management impacts on Calypso® mango fruit weight, sunburn, blush and scale damage – Dale Bennett (QDAF) ○ Mango Project updates for the NT – Upendra Shekhawat (NT DITT) ○ Water Productivity, Efficiency and Sustainability in Tropical Horticulture – Dianna Renfree (NT Farmers) ○ Q & A panel (15 mins)	**Post-Harvest** (M11) MC – Trevor Dunmall (AMIA) ○ Advancing Biosecurity: A 2D X-ray Imaging Approach for Detecting Mango Seed Weevil – Jiasheng Su (CSIRO) ○ Maturity affects internal disorders of vapour heat treated 'B74' mango fruit – Andrew Macnish (QDAF) ○ Honey Gold mango supply chain monitoring identifies means to improve quality and shelf life – John Agnew (QDAF) ○ Supply chain simulations quantify handling impacts on fruit quality and shelf life for 'Honey Gold' mangoes – Hung Duong (QDAF & NT DITT) ○ Q & A panel (15 mins)
12:20 – 1:30pm	Lunch + Posters	

1:30pm – 3:00pm	**Technology & Innovation** (M9 & M10) MC – Marine Empson (AMIA) ○ Progress in 'mango-tech' for forecast of harvest timing and load… and harvest – Kerry Walsh (CQU) ○ Technology for estimation of fruit sizing on tree – Maisa Pereira (CQU) ○ Advances in estimation of fruit attributes using NIRS – Zhenglin Wang (CQU) ○ Orchard Management Information System for harvest forecast – Hari Dhonju (CQU) ○ Machine harvesting – Rafael Goulart (CQU) ○ Q & A panel (15 mins)	**Pest & Disease** (M11) MC – Dale Bennett (QDAF) ○ Investigations into mango defence responses to safeguard the future of the Australian mango industry – Chelsea Moore (NT DITT) ○ Mango Twig Tip Dieback - Chelsea Moore (NT DITT) ○ Exploring the Impact of Tree Architecture on Mango Scale Populations – Jodie Cheesman (QDAF) ○ Using different modes of action to build the best insecticide spray program – Shaun Hood (Syngenta) ○ Launch of the mango pest and disease guide – Brian Thistleton (NT DITT) ○ Q & A panel (15 mins)
3:00pm – 3:30pm	Afternoon tea	
(M9 & M10) 3:30pm – 4:45pm	**Physiology** MC – Geoff Dickinson (QDAF) ○ Investigating Plant Growth Regulators and the molecular interactions associated with mango premature fruit drop – Sophie Jones (UQ) ○ Mango leaves are adaptable to light intensity, but productivity is limited in low light conditions – Ryan Orr (QDAF) ○ Comparing carbohydrate reserves and tree productivity in two mango cultivars under high and low planting density – Gerhard Rossouw (QDAF) ○ Manipulating flowering and harvest timing – Marcelo Amaral (CQU) ○ Q & A panel (15 mins)	
4:45pm – 5:00pm	Symposium close	



Session: Breeding, genomics & varieties

Optimization of selection in the progenies of *Mangifera indica*

Asjad Ali, Ian Bally, Bernardo Blanco-Martin, Cheryldene Maddox
Queensland Department of Agriculture and Fisheries, Mareeba, QLD 4880

Mango (*Mangifera indica* L.), an allopolyploid (2n = 40), is one of the economically grown fruits in the tropics and subtropics around the globe. Investigating the genetic inheritance of traits in mango is complicated due to difficulties in generating suitable populations, high heterozygosity and the lack of information on heritability of various traits. We estimated BLUP-based breeding values in selected full-sib and half-sib segregating progenies from the Queensland mango breeding program to assist in the selection of superior mango individuals and parents. The analysis used data measured over 10 years from over 900 individuals in 17 families. The traits measured on ripe mango fruit were fruit weight, fruit firmness, fruit blush colour, total soluble solids (TSS), skin thickness and fruit blush percentage. Linear Mixed Models were fitted to estimate the BLUP-based breeding values that subsequently were used to identify the most promising hybrid progenies and candidates as advanced lines. These statistical methods permit exploration of heritability and the stability of genetic correlations between traits over years and sites. The estimated genetic parameters for fruit quality traits can also be useful in formulating informed strategies to breed market-oriented mango varieties.

Genome assembly and evolutionary relationships of *Mangifera indica* and related species

Upendra Kumari Wijesundara[1], Agnelo Furtado[1], Natalie L Dillon[2], Ardashir Kharabian Masouleh[1], Robert J Henry[1]
[1] Queensland Alliance for Agriculture and Food Innovation, University of Queensland, Brisbane, 4072 Australia
[2] Department of Agriculture and Fisheries, Mareeba, 4880, Australia

Mango (*Mangifera indica*) is one of the most economically successful fresh fruits cultivated in tropical and subtropical regions in the world. Other than cultivated mango, wild relatives also have horticulturally important traits. However, current knowledge of the relationships between wild and cultivated mangoes, and among the commercially cultivated mangoes is mainly based on molecular markers which are not very informative. We used whole chloroplast genomes and a set of single-copy nuclear genes to get a better understanding of the relationships among 14 important *Mangifera* species and 43 commercially cultivated mangoes. Analyses of important traits at the gene level and their expression require high-quality reference genomes and transcriptomes. Currently published genomes have relatively less contiguity and completeness. Therefore, we sequenced two *M. indica* cultivars and a wild relative using highly accurate HiFi sequencing to understand the genetic basis of traits such as flavour and disease resistance. Together with the developed mango transcriptome, these genetic resources can be efficiently applied in studies analysing inheritance patterns of traits and to select parents for breeding programs.

The development of high efficiency, dwarfing rootstocks for the Australian mango industry.

Ryan Orr, Paula Ibell, Cheryldene Maddox, Asjad Ali, Zac Scobell, Ian Bally
Queensland Department of Agriculture and Fisheries, Mareeba, QLD 4880

Highly productive and dwarfing rootstocks have accelerated adoption of high efficiency production systems in crops such as apple, cherry, and grapes. In Australia, Kensington Pride is the industry standard mango rootstock due to its polyembryonic seed and widespread availability, though there is little evidence of its superiority to other rootstocks. In this presentation we will report on the past and future research to identify dwarfing rootstocks for the major Australian mango varieties. An initial six-year screening trial of 97 rootstocks was conducted at the Walkamin Research Station. From that screening trial, three promising candidate rootstocks have been selected and included in a replicated trial with the major commercial scion varieties (Kensington Pride, R2E2, Honey Gold, Calypso, Yes!!). We will outline the state of this research, findings, and future plans for this important topic.

Using functional genomics approaches to study mango flowering

Stephanie Kerr[1,2], Zachary Stewart[1], Amanda Johnson[1,2], Natalie Dillon[3], Peter Prentis[1,2]

[1]School of Biology and Environmental Science, Queensland University of Technology, Brisbane, QLD, 4000, Australia
[2]Centre for Agriculture and the Bioeconomy, Queensland University of Technology, Brisbane, QLD, 4000, Australia
[3]Department of Agriculture and Fisheries, Mareeba Research Facility, Mareeba, QLD, 4880, Australia

Flowering is a complex process regulated by many different environmental signals and endogenous signalling pathways. Much of what we understand about the genetic pathways controlling flowering has come from studies in model species, although studies in tree species indicate that many of the genetic pathways regulating flowering are highly conserved. However, our knowledge of the genetic pathways that control flowering in mango is still limited. As part of the National Tree Genomics program, we are using various functional genomics approaches to identify key flowering genes in mango and functionally characterise these genes in model plants. We are also exploring novel techniques, such as the use of nanoparticles to silence endogenous gene expression, to examine function of these genes within the mango tree itself. This research aims to improve our understanding of the genetics controlling flowering in mango and use this knowledge to enhance the breeding of improved cultivars. Here, I will present our latest research and update our understanding of the genetic pathways regulating flowering in mango.

Facilitating adoption of new technologies in the Australian mango industry.

Geoff Dickinson[1*], Dale Bennett[1], Ian Bally[1], Ryan Orr[1], Gerhard Rossouw, Marine Empson[2], Salman Quddus[3], Michael Finney[3], Andrew Robson[4], and Kerry Walsh[5].
[1]Department of Agriculture and Fisheries, Mareeba, Queensland, [2]Australian Mango Industry Association, Cairns, Queensland, [3]Department of Innovation, Tourism and Trade, Katherine, Northern Territory, [4]University of New England, Armidale, New South Wales and [5]Central Queensland University, Rockhampton, Queensland.
*Corresponding author Geoff.dickinson@daf.qld.gov.au

The Australian mango industry is a high-value industry, widely distributed across Australia's remote, northern tropics. This industry faces challenges including long supply chains, variable climate, labour shortages, increasing input costs, and inconsistent fruit quality. The Mango Industry Strategic Plan (2022-26) identifies the adoption of intensive mango practices and the development of new ag-technology, as key solutions to increasing industry efficiency, profitability, and sustainability.
This paper describes the extension and communication methods used to facilitate industry awareness and adoption of new practices and technologies, within two national Hort Innovation funded projects, 'National Tree Crop Intensification in Horticulture Program' (AS18000) and the 'Multi-scale Monitoring Tools for Managing Australian Tree crops' (ST19000).

These cutting-edge projects incorporate an integrated research, development and extension structure, with objectives to 1) Investigate and progress the knowledge and understanding of increased mango orchard intensification methods and technologies, with goals to improve orchard efficiency, productivity and profitability and 2) Communicate, demonstrate and extend these latest findings and recommendations to support mango industry stakeholders to make informed decisions which improve their management practices.
Communications and extension within these projects involve a highly integrated approach using multiple techniques. The primary method has been the establishment of experimental research and best-bet practice demonstration sites on government research stations and on commercial growers' properties. These resources, developed, established, and managed in collaboration with industry experts and growers provide the factual results, information, and examples used to inform the wider mango industry. Several demonstration sites were established independently of these projects, with growers being approached and then agreeing to share this information with the wider mango industry.

This strategy known as 'Farmer Participatory Research' harnesses the farmers practical experience and expertise, to improve the value of innovative technologies and improved practices, which then facilitates greater industry adoption.

Planting density and canopy management impacts on Calypso® mango fruit weight, sunburn, blush and scale damage

D. Bennett, C. Wright, I. S. E Bally, and R. Orr
Department of Agriculture and Fisheries, Mareeba, Queensland

The mango industry is globally shifting towards high-density orchards to boost productivity per unit area, drawing inspiration from the success seen in temperate crops like apple and pear. However, the adoption of these new planting systems brings about a mix of positive and negative impacts on various fruit quality characteristics. To investigate if similar effects are observed in mango cultivation in Australia, we conducted a study on 9-year-old Calypso® mango trees grown at planting densities of 208 or 1250 trees per hectare with conventional canopy management, as well as in espalier trellis trained trees planted at 1250 trees per hectare. Each treatment included six replicate trees arranged in randomised blocks. The assessment involved weighing all fruit in the experimental trees, quantifying sunburn and blush area, and counting scale damage 'pink spots'. The evaluations were carried out over the 2022/23 and 2023/24 growing seasons at the Planting Systems Trial at Walkamin Research Facility. The results showed that mean fruit weight per tree was significantly lower in high-density planted trees but did not show significant differences between the two canopy training systems. Interestingly, this trend was not observed in other varieties like Keitt and Yess! (Formerly NMBP-1243). This highlights that for certain varieties, planting at higher densities can lead to competition among fruits for limited resources, resulting in reduced fruit weight. Scale damage emerged as the primary cause of fruit downgrades, especially in low-density systems. While sunburn damage was more prevalent in trellised systems, it led to fewer rejected fruits compared to scale damage. This underscores that although trellis systems may increase sunburn incidence due to enhanced light interception, the advantages of narrower canopies, such as improved spray penetration for better pest management, ultimately contribute to an overall enhancement in fruit quality. These results suggest that effective management of crop inputs is essential in high-density orchard systems to mitigate competition effects on fruit weights, and the adoption of narrower canopies can lead to an overall improvement in fruit quality.

Mango RD&E in the Northern Territory

Dr. Upendra Shekhawat, Plant Industries, Department of Industry, Tourism and Trade, NT.

Mangoes are the Northern Territory's major horticultural commodity, with the industry generating more than $128 million in revenue and employing over 3500 people during harvest season. Territory mango farmers produce 52% of Australia's output and provide the first crop of the season to Australian consumers. The NT Government's department of primary industries has been researching mangoes for several decades. Apart from industry-funded research trials, we have partnered with universities and other RDCs over the years to investigate mango physiological characteristics, varietal performance, flowering dynamics, automation of harvesting, disease pressure, and supply chain logistics. Further efforts are underway to develop solutions for improved yield and quality, extended shelf life and improved genetic resources for mangoes in the NT.

Water Productivity, Efficiency and Sustainability in Tropical Horticulture.

Dianna Renfree, NT Farmers

The project has been investigating current irrigation practices in the Greater Darwin region of the Northern Territory (NT), to make recommendations to growers aimed at improving water use efficiency and integrating best practice into decision-making processes. The project established research sites within existing commercial production systems amongst identified key industry champions. A critical component of the project is focusing on maintaining soil moisture monitoring sites which help monitor and establish baseline information which will develop best irrigation practice benchmarks.

Session: Post-Harvest

Advancing Biosecurity: A 2D X-ray Imaging Approach for Detecting Mango Seed Weevil (*Sternochetus mangiferae*) Infestations in Fresh Agricultural Produce

Maryam Yazdani[1], Jiasheng Su[1], Ben James[2], Yi Liu[2]

[1] CSIRO Health & Biosecurity, Ecoscience building, Dutton park, Brisbane, QLD, 4001, Australia

[2] CSIRO Mineral Resources, Building 67, ANSTO, New Illawarra Road, Lucas Heights, Sydney, NSW, 2234, Australia

The mango seed weevil (MSW), *Sternochetus mangiferae*, poses a significant threat to the mango industry, especially in regions where its quarantine status hinders shipments to pest-free areas. During egg-laying, the weevil creates a minute incision in the fruit, with the ensuing sap flow enveloping the egg case. Although MSW is considered a minor pest, its hidden presence within the seed poses challenges for symptom detection at harvest.

Our project addresses these challenges by developing a state-of-the-art solution for non-destructive pest detection. Leveraging 2D X-ray imaging technology, we aim to identify MSW infestations in fresh agricultural produce. Inspired by successful applications in security contexts, our adaptation of this technology allows us to pinpoint internal feeding damages, larval instars, and pupae within mango seeds. Our study demonstrates the potential of 2D X-ray imaging as a rapid, precise, and automated quarantine system for biosecurity threats.

Our research includes the design and implementation of a sophisticated X-ray imaging (2D&3D) system, supported by advanced algorithms and innovative encoding strategies to further improve imaging speed in future. The integration of cutting-edge hardware and machine learning techniques enhances the speed and accuracy of MSW identification, offering a pragmatic solution for pest quarantine systems. This interdisciplinary approach aims to contribute to preventing MSW incidence, safeguarding the economic interests of mango producers, and ensuring the quality of exported produce.

Maturity affects internal disorders of vapour heat treated 'B74' mango fruit

A. Khanal, D. C. Joyce, M. A. Ullah, D. E. Irving, A. J. Macnish, P. A. Joyce, N. A. White, E.W. Hoffman, and R. I. Webb

Mango fruit are susceptible to internal disorders (IDs), including flesh cavity with white patches (FCWP) and flesh browning (FB). IDs adversely affect consumer satisfaction and repeat purchasing behaviour. The incidence and severity of fruit disorders are typically influenced by genetic, environmental, and management factors. Among these, harvest maturity is generally important. This study sampled fruit subject to vapour heat treatment (VHT) from two export supply chains upon their arrival at a commercial VHT facility. Individual fruit maturity was assessed initially as dry matter content (DMC) by near infrared (NIR) handgun, and they were grouped into three maturity classes; 'less mature' (<15% DMC), 'mature' (15-17% DMC), and 'more mature' (>17% DMC). Thereafter, all fruit were kept at 20-22 °C and 90% relative humidity (RH) until eating ripe as determined by hand firmness. Thereupon, each fruit was cut and assessed for incidence and severity of IDs. Both IDs were influenced by fruit maturity. Fruit with lower DMC (<15%) had significantly (p<0.05) higher FCWP incidence and severity. Fruit with higher DMC (>17%) had significantly higher FB incidence and severity. Hence, incidence and / or severity of FCWP and FB can potentially be minimised by harvesting or sorting for DMC prior to VHT.

Honey Gold mango supply chain monitoring identifies means to improve quality and shelf life

John Agnew[1], Andrew Macnish[1], Alan Niscioli[2]
[1] Queensland Department of Agriculture and Fisheries
[2] Northern Territory Department of Industry, Tourism and Trade

Piñata Farms sources the Honey Gold (HG) mango variety from all major mango districts in Australia, each experiencing variable production conditions and distances to market. Concerned about not maximizing quality and market opportunities, they engaged the Serviced Supply Chains II (AM21000) project to monitor several commercial consignments and conduct detailed time by temperature trials to simulate the variation and evaluate the impact on quality and shelf life.
The project team monitored 16 HG consignments using real-time temperature loggers from northern Australia to Melbourne's wholesale trading centre in 2022/23 season. The mangoes were assessed for initial quality and then stored at 20°C, with their shelf life determined by firmness and the presence of major defects such as rot.
The study found that average supply chain temperatures ranged from 13.5 to 21.0°C, often exceeding recommended levels, affecting product shelf life, which varied from 5 to 19 days. Dispatch temperature, average temperature and maximum temperature exceeded the recommended in 43%, 36% and 64% of consignments monitored respectively. Other issues identified included rainfall close to and during harvest, which initiated rapid disease development affecting fruit quality.
Sharing the data with supply chain partners has prompted moves to improve dispatch and transport temperatures plus greater attention to orchard and packshed fungicide management. The project's findings are relevant to all mango growers, emphasizing the importance of supply chain management in maintaining fruit quality.

Supply chain simulations quantify handling impacts on fruit quality and shelf life for 'Honey Gold' mangoes

Hung Duong[1], Pip Bryant[1], Lawrence Smith[1], Andrew Macnish[1], Saeedeh Taghadomi-Saberi[2]
[1] Queensland Department of Agriculture and Fisheries
[2] Northern Territory Department of Industry, Tourism and Trade

Over the 2021/22 and 2022/23 growing seasons, 'Honey Gold' mango fruit were harvested at commercial maturity (e.g. 15.9-18.5% dry matter content) from five farms in the Northern Territory and Queensland. Fruit were stored at 8°C to 20°C for up to 32 days to simulate a range of supply chain conditions. Sub-samples of fruit were removed from storage every 4 days and transferred to 20°C to evaluate remaining shelf life. Some fruit samples were also treated with 100 ppm ethylene at 18°C for 2 days prior to shelf life. In general, storage at 10 and 12°C provided the greatest residual shelf life. Fruit maintained at 8°C for at least 20 days often developed chilling injury, although this varied between the farms. Fruit softening and the loss of residual shelf life occurred more rapidly as storage temperatures increased from 14°C to 20°C. Treating fruit with ethylene accelerated uniform ripening by about 2-3 days relative to non-treated fruit. A strong relationship (i.e. r^2 = 0.85 to 0.92) between cumulative time x temperature units and remaining shelf life existed, which suggests predictive models could be developed to guide distribution and marketing decisions. The Serviced Supply Chains II (AM21000) project is developing decision support tools for growers and their supply chain partners to deliver mango fruit with more predictable quality and shelf life.

Session: Technology & Innovation

Progress in 'mango-tech' for forecast of harvest timing and load…and harvest

Kerry Walsh, CQUniversity

A review is presented of past, current and developing 'harvest' technologies, focusing on mango but drawing on developments from other areas. Topics will include (i) tools for the forecast of time at which fruit harvest maturity will be reached, involving temperature logging and heat unit estimation and assessment of flowering, and estimation of NIR-dry matter content ; (ii) estimation of fruit load (fruit number and size on tree), (iii) harvesting technologies and (iv) postharvest technologies. The limitations of manual methods in terms of a statistically valid sampling strategy, and limitations of 'automated' methods relying on machine vision will be explored. Disparities between commercial application and the scientific literature base will be highlighted, providing suggestions for future lines of development.

Technology for the estimation of fruit sizing on tree

Maisa Pereira, Anand Koirala, Kerry Walsh
CQUniversity

Pre-or at- harvest estimation of fruit mass distribution is useful for marketing purposes and for grading line set-up. The mass of mango fruit on tree can be estimated from measurements of fruit length, width, thickness and/or area, with a typical R2 >0.9 and RMSE of <30 g. Three methodologies for the forward estimation of the fruit size at harvest are compared, with recommendations based on accuracy, ease of use, and cost: (i) manual estimation based on 'traditional' caliper measurements, (ii) manual estimation based machine vision app on mobile phone, and (iii) machine vision involving drive-by imaging using a RGB-depth camera. The use of a mobile device app for field data collection is described, with implementation of a systematic sampling protocol. Forward estimation of fruit size at harvest from measurements taken weeks before harvest will be demonstrated based on fruit growth models developed in context of cultivar and growth conditions.

Advances in estimation of fruit attributes using NIRS

Zhenglin Wang, Jeremy Walsh, Arjun Neupane, Kerry Walsh
CQUniversity

Near infrared spectroscopy (NIRS) has been used by the Australian mango industry in the non-invasive assessment of dry matter content of fruit for over two decades, with a focus on use with fruit on tree rather than on packline. Over this period, there has been an evolution in the modelling techniques used, from multiple linear regression to partial least squares regression, and more recently, to use of artificial neural networks. The use of 1 dimensional convolutional neural networks (CNNs) is now topical. The primary goal in this evolution is for a model robust in performance, across cultivars, growing conditions, instruments and instrument aging. Using a mango DMC calibration and test set (of >10,000 data records) which we have made publicly available, a new benchmark for RMSEP on the test set of 0.77 %FW was achieved using a 1D-CNN model, being statistically lower than that reported using PLS, ANN or other CNN models. This CNN model was also achieved a superior result with another season of fruit than the ANN and PLS models, with RMSEPs of 1.18, 2.62, and 1.87, and Bias of 0.16, 2.36 and 1.56 %FW, respectively. The importance of the combination of data augmentation and model type will be demonstrated, and attempts to interpret the CNN model using techniques such as GradCam will be presented. Neural network model training was demonstrated to be sensitive to the use of differing seeds with a standard deviation of 0.03 and 0.02 %FW noted for RMSEP of 50 ANN and CNN models, using different random seeds, respectively. The potential for adoption by the mango industry will be discussed.

Orchard Management Information System for harvest forecast

Hari Dhonju, Thakur Bhattarai, Kerry Walsh
CQUniversity

Timely and accurate forecasting of harvest timing and load are paramount essential for mango growers and the industry to support decision making in harvest management, e.g., hire of harvest labour, postharvest management, e.g., organizing transport, and marketing, to improve productivity and reducing the waste of mangoes.

The development and use of farm management information systems (FMIS) for tree fruit applications lag those targeted to broadacre cropping applications. Using design science principles, we propose a FMIS to integrate the available harvest forecasting technologies, involving systems as diverse as temperature logging to machine vision. A spatially enabled cloud-based orchard management information was developed as a progressive web application for mango harvest forecast. Inputs to the platform include 15-minute interval temperature data, human and machine vision estimates (flowering levels, fruit load and fruit size) and dry matter. Data is uploaded either manually or automatically through RESTful APIs. The key components are (a) data acquisition and management, (b) harvest forecast engine and (c) WebGIS and visualization. Design requirements include accuracy of prediction, system responsiveness, spatial and tabulated display, etc. Operation of the system will be demonstrated.

Machine harvesting

Rafael Goulart and Kerry Walsh
CQUniversity

Shortages and high labour costs pose challenges to labour-intensive agricultural operations, notably soft tree-fruit harvesting. While mechanical solutions exist for heavy produce like potatoes and dry fruit such as macadamia, solutions for soft fruit, like mangoes, are underdeveloped. This study aimed to enhance a prototype mango harvesting solution by improving performance through three activities. First, a low-cost method ($20 per piece) was devised for producing non-perishable fruit phantoms using silicone, allowing for comparative assessment of harvester hardware. Second, performance metrics were developed for evaluating end-effector designs and harvest strategies, including laboratory and orchard trials. One design utilizing six flexible fingers achieved promising results, with a picking area of ~150 cm^2 and a picking volume of 467 cm^3 in laboratory trials, and a detachment and harvest efficiency rate of 74% and 65%, respectively, in orchard trials. Third, strategies involving manipulator coordination and fruit picking prioritization were compared, resulting in notable reductions in cycle time per harvested tree and fruit. These findings offer insights into improving mango harvesting efficiency and minimizing postharvest damage, thereby contributing to the advancement of soft fruit harvesting technologies.

Session: Pest & Disease

Investigations into mango defence responses to safeguard the future of the Australian mango industry

Chelsea Moore[1], Stephanie Kerr[2]
[1] Department of Industry, Tourism and Trade, Northern Territory Government of Australia;
[2] Queensland University of Technology

The Australian horticulture industry needs to invest in strategies to remain viable in the face of current trends for horticultural produce with a low environmental impact and reduced reliance on pesticides. This work explores varietal level responses of commercial Australian mangoes to biotic challenges. Understanding the plant defence responses specific to individual commercial mango varieties can provide a basis for improved disease management options, including Integrated Pest Management (IPM).

Mango Twig Tip Dieback: a review

Chelsea Moore, Alan Niscioli, Constancio Asis, Michael Finey, Sharl Mintoff, Stan Bellgard and Upendra Shekhawat.

Department of Industry, Tourism and Trade; Northern Territory Government of Australia.

In recent years, mango twig tip dieback has been a significant issue reported by mango growers in the Darwin region of the Northern Territory. Typically starting out as a dark-coloured lesion on one side of mango twigs, and buds of the most recent flush, entire leaves die as the lesion extends along the twig, eventually killing the whole branch. These symptoms appear atypical for the causal agents of common mango dieback (i.e. pathogens from the Botryosphaeriaceae family). This review covers the disease surveys, pathogen isolation, pathogen screening, and inoculation trials undertaken to elucidate the causes of this apical necrosis.

"Branching Out: Exploring the Impact of Tree Architecture on Mango Scale Populations"

Jodie Cheesman
Queensland Department of Agriculture and Fisheries

The relationship between tree architecture and mango pest populations is a critical aspect of agroecosystem dynamics. This study investigates how the structural features of mango trees influence the abundance and distribution of mango scale (*Aulacaspis tubercularis*), ultimately impacting crop health and yield.

Understanding the effect of tree architecture on mango pest populations is essential for developing sustainable pest management strategies. Certain architectural traits may provide refuge for pests, offering hiding places and favourable conditions for reproduction. Conversely, specific tree structures might deter pests by limiting access to resources or creating inhospitable environments.

A five-year experiment compared mango scale populations on three mango varieties grown in two different densities using three different training systems. The findings reveal mango scale populations both on foliage and fruit in high density planting systems are lower than in conventionally spaced, low density planting systems.

Insights from this research can guide orchard management practices, informing decisions on tree pruning, spacing, and overall orchard design to mitigate pest infestations.

Using different modes of action to build the best insecticide spray program

Shaun Hood, Syngenta

Chewing and sucking insect pests attack mangoes throughout the season; among the more challenging to control are the flower eating caterpillar, scale insects, plant hoppers, fruit spotting bugs and mango seed weevil. While beneficial insects play an important role in managing these pests, growers will often need to use an effective insecticide to control certain pests at critical times throughout the year. Unfortunately, the repeated use of insecticides with the same mode of action is a recipe for disaster, as pests have the ability to become resistant to the 'old favourites'.

The good news is, Syngenta has been working on a new insecticide for the mango industry. VERTENTO® insecticide*, powered by PLINAZOLIN® Technology, is unlike any other insecticide currently on the Australian market. When registered, VERTENTO® will be the first Group 30 insecticide available for use in trees crops. To ensure this product remains an invaluable tool for resistance management over the long term, it's use will need to be carefully managed.

* VERTENTO is not a registered product. An application for registration is currently with the Australian Pesticide and Veterinary Medicines Authority (APVMA).

Launch of the mango pest and disease guide

Brian Thistleton

Department of Industry, Tourism and Trade; Northern Territory Government of Australia.

Session: Physiology

From signals to shedding: Investigating the molecular interactions associated with mango premature fruit drop

Sophie Jones[1,2], Ryan Orr[4], Gerhard Rossouw[4], Harley Smith[5], Christine Beveridge[1,2], Lindsay Shaw[1,2,3]

[1] School of Agriculture and Food Sustainability, University of Queensland, St Lucia, QLD, Australia

[2] ARC Centre of Excellence for Plant Success in Nature and Agriculture, University of Queensland, St Lucia, QLD, Australia

[3] Queensland Alliance for Agriculture and Food Innovation, University of Queensland, St Lucia, QLD, Australia

[4] Department of Agriculture and Fisheries, Mareeba, QLD, Australia

[5] CSIRO Agriculture and Food, Waite Campus, South Australia

Preharvest fruit drop poses a significant challenge to Australian mango producers, yet the underlying processes regulating fruit abscission are poorly understood. The availability of carbohydrates, along with environmental, genetic, and hormonal cues can influence the proportion of mango fruit that are carried through to harvest. Plant hormones have been applied to tree crops in the form of plant growth regulators (PGRs) to improve flowering, fruit set, and fruit retention, however, results of PGR usage in mango have been inconsistent. It is thought that PGR applications influence plant growth traits by altering naturally occurring hormone signals, either by supplementing low levels or interacting with the signalling pathway. Field trials have been conducted exploring the effect of PGRs, including 1-naphthaleneacetic acid (NAA), a synthetic auxin, gibberellic acid (GA_3), a natural

gibberellin, and N-(2-Chloro-4-pyridyl)-N'-phenylurea (CPPU), a synthetic cytokinin, on reducing mango fruit drop. Molecular and genetic techniques such as hormone quantification, sugar and starch measurements, and gene expression studies are being used to understand the response to PGR treatment and changes in carbohydrate availability. This will help improve understanding of the molecular mechanisms controlling fruit abscission in mango and identify potential strategies to control preharvest fruit drop.

Mango leaves are adaptable to light intensity but productivity is limited in low light conditions.

Presenter: Ryan Orr
Authors: Alexander W. Cheesman, Kali B. Middleby, Gerhard Rossouw, Lucas A. Cernusak, Ian Bally, Ryan Orr

Department of Agriculture and Fisheries, Mareeba Research Facility, Peters Street, Mareeba, Queensland 4880, Australia.

Mango canopy management is an area of emerging research driven by the need to increase productivity and fruit quality, while responding to emerging threats such as increased temperature and pest pressure. Options such as protected cropping or altered canopy shapes will change the intensity and quality of light available for mango leaves to use in photosynthesis though the potential effect of these changes is poorly understood. In this study the morphological and functional differences of 68 Calypso™ cultivar leaves of the same age were assessed across a light intensity gradient from full sun to full shade prior to flowering. Leaf photosynthetic parameters, dry matter, and concentration of photosynthetic and stress related pigments were assessed. We found that at low light intensity leaves have limited productivity, though require little resource investment. Low light leaves appear to have limited net productivity and may in fact require more resources than they produce at certain times. Leaf productivity appears to increase with light intensity to the maximum intensity tested. This is contrary to expectations as excess light stress does not appear to be interfering in leaf productivity. It is possible that this discrepancy is due to related environmental factors such as leaf temperature or water availability which requires further investigation. These findings will support efforts to improve canopy management or institute protected cropping solutions to meet future mango production challenges.

Comparing carbohydrate reserves and tree productivity in two mango cultivars under high and low planting density

Presenting author: Gerhard Rossouw
Co-authors: Ryan Orr, Ian Bally, Geoff Dickinson

Department of Agriculture and Fisheries, Mareeba Research Facility, Peters Street, Mareeba, Queensland 4880, Australia.

Increasing tree density in mango orchards is key for boosting fruit productivity per land area. However, higher planting density leads to smaller canopies and reduced yields per tree. This study aimed to explore the link between non-structural carbohydrate concentrations and fruit yields per tree under different planting densities. Starch and sugars in roots and scion trunk wood were compared between two mango varieties, NMBP-1243 and Keitt, at densities of 208 and 1250 trees per hectare. Samples were collected from six trees of each cultivar at both densities. Baseline carbohydrate reserves as

influenced by prior cropping was established, carbohydrate replenishment before the next fruiting cycle was assessed, and carbohydrate usage during fruit growth was evaluated. The relationships between fruit numbers and weights from the previous and next harvests, and tree carbohydrate status, were subsequently examined. Compared to NMBP-1243, Keitt trees rely more heavily on carbohydrate reserves to produce higher yields but replenish their reserves faster between fruiting cycles. Planting density exhibits minimal impact on carbohydrate reserve dynamics for NMBP-1243. However, lower planting density appears to benefit root starch in Keitt. Carbohydrate regulation shows variability among mango cultivars under high and low planting density conditions, consequently influencing tree capacity for fruit production.

Manipulating flowering and harvest timing

Marcelo Amaral[1], Geoff Dickenson[2], Cameron McConchie[3], Kerry Walsh[1]
[1]CQUniversity
[2] Department of Agriculture and Fisheries, Mareeba, QLD, Australia
[3]

In Australia, the harvest window for commercial mango production effectively begins in Darwin from late August and finishes in southern Queensland and the southwest of WA in March. The harvest window is determined by time of flowering and temperature during the fruit development period. Flowering is induced on hardened vegetative growth by several days of low temperatures. Paclobutrazol and a series of practices have been used to manipulate flowering in warmer weathers but these practices are not well documented for the Australian production system. The timing of harvest maturation can be forecast based on heat units (also known as Growing Degree Days, GDD). Three activities are being undertaken in the 2023/24, 2024/25 and 2025/26 seasons with the aim of providing growers with recommendation of practices for the manipulation of harvest window: (i) an investigation of the use of growth regulators and fertilizer sprays to delay vegetative growth and induce flowering; (ii) documentation of the temperature requirements for flower induction in a number of cultivars, with integration of climate models to forecast impact on frequency of inductive conditions in different mango production regions; (iii) validation of GDD requirements for most cultivars grown in Australia. Results from the 2023/24 season will be presented.

POSTERS

Bee-ing fruitful: Healthy pollinators supported by the mango industry

Plant Health Australia, Kathryn Pagler

Abstract:

Mangos rely on a range of insect pollinators, including some visitation by honey bees to increase fruit set production. In recognition of this reciprocal relationship, the mango industry works collaboratively with the honey bee industry via Hort Innovation, through their investment in the National Bee Pest Surveillance Program (NBPSP).

Delivered by Plant Health Australia (PHA) with additional funding from the Australian Government, the Australian Honey Bee Industry Levies and Grain Producers Australia, the NBPSP supports early detection for high priority exotic bee pests, including Varroa mite, Tropilaelaps mite and Tracheal mite.

The NBPSP uses a range of surveillance methods at seaports and airports throughout Australia, since these are the most likely entry points for honey bee pests and pest bees. Surveillance at additional ports is also provided through in-kind contributions by state and territory governments.

Since the commencement of the NBPSP in 2012, more than 30,500 surveillance activities have been performed. Surveillance tactics employed in the program include monitoring live (sentinel) hives for pests and diseases, catchboxes to capture swarms, rainbow bee-eater pellet analysis and aerial pheromone ballooning to pick up new species of bees and using nets to sweep flowering plants to capture any foraging bees near ports.

Stingless bee visitation, cross-pollination and fruit set in co-flowering Kensington Pride and R2E2 orchard near Darwin

James C Makinson[1]*, Patsavee Utaipanon[1], Anushika De Silva[1], Joel Nichols[2], Steven Trueman[2] and James Cook[1]

[1] Hawkesbury Institute for the Environment, Western Sydney University, Richmond, New South Wales 2753, Australia

[2] Food Futures Platform, Centre for Planetary Health and Food Security, School of Environment and Science, Griffith University, Nathan, Brisbane, Queensland, Australia

Recent work by our team, funded by Hort Innovation grant “Stingless bees as effective managed pollinators for Australian horticulture (PH16000)”, demonstrated that wild stingless bees are effective mango pollinators on Darwin farms that are surrounded by stands of native vegetation providing suitable habitat. For Hort Innovation grant “Crop and varietal data to better understand the importance of pollination (PH20001)” we wanted to test whether deploying managed colonies of this NT local stingless bee species, *Tetragonula mellipes*, would lead to higher rates of cross-pollinated fruits in an orchard containing KP and R2E2 trees. We monitored insect visitation throughout the flowering period on 9 KP and 9 R2E2 trees adjacent to one another and located between 0m and 100m from a block edge next to native vegetation. In the middle of the flowering period we introduced 12 stingless bee colonies to the orchard. Stingless bee floral visitation increased for a 2 week period after hive deployment. Overall, 15.6% of KP fruit (n=109), and 26.0% of R2E2 fruit (n = 104) were cross-pollinated. Stingless bee visitation does not appear to influence mango cross-pollination. We are

conducting nutrient analysis to determine whether cross-pollinated KP or R2E2 fruit are of superior quality to self-pollinated fruit.

Factors affecting flesh colour in mangoes (*Mangifera indica L.*) and their subsequent health benefits.

Tatsuyoshi Takagi, University of Queensland

Mango flesh colour is a key consumer preference trait, with an increasing importance due to the popularity of pre-cut fruits. The flesh colour in mango can largely differ from cultivar to cultivar, and the differences are mainly attributed to the carotenoids. Carotenoids are naturally synthesised pigments and are widely known for the antioxidant and provitamin A health benefits. My project consists of identifying the key factors which affect the flesh colour. This consists of employing molecular analyses to identify genetic markers in hopes to assist in the breeding program for selected flesh colour traits.

This project has achieved results by obtaining objective colour measurements of 25 mango varieties ranging from pale-yellow to dark orange, analysing the carotenoid profile to identify key differences within colour groups and conducting ripening trials to identify colour changes over time. In addition to this, a genome-wide association study (GWAS) was also conducted on 201 varieties of mangoes utilising 871835 single nucleotide polymorphisms (SNP). The next step is to use molecular techniques such as RNA extractions and mRNA sequencing to identify potential genes of interest and performing further functional analysis on them.

Area-Wide Management Approaches for Fruit Flies in Indonesia

Stefano De Faveri[1] S, Vijaysegaran[2], Affandi[3], Hendri[4], Deni Emilda[4], Ellina Mansyah[3], Waryana[5], Cecep Kurnia[6], Peter Johnson[7] and Jodie Cheesman[1]

[1]Department of Agriculture and Fisheries, Australia. [2]Entomology Consultant, Brisbane, Australia; [3]National Research and Innovation Agency, Indonesia; [4]Indonesian Tropical Fruit Research Institute - Indonesian Centre for Horticulture Research and Development, Solok, Indonesia; [5]Angling Darma Farmer Group, Krasak, Indonesia; [6]Food and Horticultural Crop Protection Agency of West Java, Sedong, Indonesia; [7]Horticulture consultant, Kununurra, Australia

Background: Indonesia is the fourth largest producer of mangoes in the world. However, production and market access are restricted by two species of fruit fly, *Bactrocera dorsalis* and *B. carambolae,* which cause significant damage to mango in Indonesia. A coordinated area-wide systems approach incorporating **male annihilation, protein bait spraying, crop hygiene and population monitoring, together with farmer training** was implemented in two production areas in West Java.

Methods: The trial sites were located at Krasak (40ha, district of Indramayu) and Sedong Lor (25ha, district of Cirebon). The orchards were surrounded by village dwellings and rice fields. The standard insecticide treated orchards used as control sites were located at Putat (45ha) and Pawidean (53ha). The male annihilation technique (MAT) blocks were **4:1 methyl eugenol and fipronil toxicant in a** 5x5cm fibreboard block. The blocks contained approximately 12 ml of product each and were nailed onto trees at 50m intervals (about 6 blocks/ha) and placed in the orchard as well as in the village. New

blocks were added every 2 months. Protein baits based on a brewery yeast by-product and containing the toxicant abamectin were applied weekly and commenced after the oldest fruits were aged 4 weeks after fruit set and continued until all fruits were harvested. Four spot sprays of 25ml each were applied per tree. Fruit was visually observed at the packhouse and samples of 100 fruit/sampling were kept and incubated for 3 days and then dissected to confirm presence or absence of eggs and larvae. Fruits were sampled monthly during the season.

Results: At the start of the AWM program in August 2019, the number of flies/trap/day (FTD) reached a high of 12.27 in Krasak and 14.24 in Sedong Lor. It then took about 6 months for the populations to reduce and stabilise to below the suppression level of <1 Fly/Trap/Day (FTD). Populations have been maintained below the suppression level of <1 FTD from the 6 month after initiation of the program until the present. In comparison, the FTD value in the control sites recorded a high of 468 in Putat and 863 in Pawidean. In 2021 the overall damage was 0.2% at Krasak and Sedong Lor. Infestation levels at insecticide treated sites, trader warehouses and local markets ranged between 6-31%.

Conclusion: Farmers are self-sufficient and able to maintain the AWM program under a coordinated approach. Expansion is planned for areas in East and West Java. The area-wide systems approach is suitable for orchards as small as 25ha and for other commodities.

Harmonic radar tracking of *Bactrocera* and *Zeugodacus* fruit flies

Stefano De Faveri[1], Nicole Miller[2], Theo Yoder[2], Nicholas Manoukis[3], Lori Carvalho[3], John Tomerini[4], Matthew De Faveri[5], Anika Hurst[2], Allison O'Brien[6], Carole Wright[1], Jodie Cheesman[1] and Matthew Siderhurst[2]

[1]Department of Agriculture and Fisheries, Mareeba, Australia. [2]Eastern Mennonite University, Harrisonburg, VA, USA. [3]USDA ARS PBARC, Hilo, HI, USA, [4]Firescape Science, Atherton Australia, [5]University of Queensland, Brisbane, Australia, [6]Bridgewater College, Bridgewater, VA, USA.

Background: Tephritid fruit flies, such as the Queensland fruit fly (Qfly), *Bactrocera tryoni*, and the melon fly, *Zeugodacus cucurbitae*, are major horticultural pests worldwide and additionally pose invasion risks. Determining movement parameters for fruit flies are critical to implementing surveillance and control strategies, particularly in the development of agent-based models. While mark-release-recapture, flight mills, and visual observations have been used to study tephritid movement, each of these techniques have limitations. Tracking tagged flies offers an alternative method which has the potential to observe individual fly movements.

Methods: Harmonic radar (HR) tags were fabricated using superelastic nitinol wire which is light (tags weighed less than 1 mg), flexible, and does not tangle. Multiple tephritid species were tagged and subjected to flight tests. Subsequent experiments successfully tracked HR tagged Qflies and melon flies in a number of environments including large field cages, papaya fields, and open parkland.

Results: Flight tests with multiple tephritid species showed mixed results in terms of adverse effects for HR tag attachment. Qfly, melon fly, *B. dorsalis*, and *B. jarvisi* wild males were all capable of flight when tagged. Individual flight distances (meters per flight) for male melon fly differed between the field cage, papaya field, and open field experiments with longer mean step-distances observed in the open field. Both melon fly and Qfly males showed similar step frequency vs. step distance relationships. A majority of tagged male melon flies showed strong flight directional biases with these

biases varying between flies, similar to what has been observed in the migratory butterfly *Pieris brassicae*. In field cages experiments, 83% of male melon flies showed directionally biased flights while similar biases were observed in roughly half the flies tracked in the papaya field. At least some of the direction bias can be explained by wind direction with a correlation observed between overall fly flight directions in the field cage, papaya field, and open field experiments. However, individual melon fly mean flight directions coincided with the observed wind direction for 9 of 25 flies in the cage experiment and half the flies in the papaya field experiment, suggesting wind is unlikely to be the only factor affecting flight direction.

Conclusion: Data on flight directions and step-distance determined in this study might assist in the development of more accurate agent-based modelling for pest tephritid species. Additionally, harmonic radar tags developed in this study allow tracking tephritid fruit flies in a variety of environments. We believe this will enable new areas of study on tephritid movement, phenology, and behaviour which will potentially improve detection and control methods.

AUSTRALIAN® MANGOES SCIENTIFIC SYMPOSIUM

20 MAY, CAIRNS

connect, inspire, innovate 2024

Our Symposium Partners

Queensland Government

NORTHERN TERRITORY GOVERNMENT

The Australian Mango Scientific Symposium has been funded by Hort Innovation using the mango research and development levy and contributions from the Australian Government.
Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Hort Innovation

Woolworths

STERITECH Protecting what matters