Hort Innovation

Final Report

Building best management practice capacity for the Australian mango industry

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Delivery partner:

Australian Mango Industry Association

Project code:

MG17000

Project:

Building best management practice capacity for the Australian mango industry (MG17000)

Disclaimer:

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Public summary

Spanning from 2018 to 2022, MG17000 *Building Best Management Practice Capacity for the Australian Mango Industry* was a continuation of MG13017 *Capacity building, information, technology and extension for the mango industry* and MG17002 *On-farm quality testing utilising near infrared (NIR) technology*. The aim of MG17000 was to build the Australian mango industry's capacity to maintain and improve orchard productivity, fruit quality and the industry's overall profitability and long-term sustainability. The project was responsible for delivering a range of resources, events and services to help the mango industry access, understand and implement best practice. This aligns with outcome 3 of the 2017-2021 Mango Strategic Investment Plan, *Increased R&D and extension capacity and resources supporting industry development*.

There were four major focus points for the project including mango industry extension, mango data collection, mango quality/dry matter testing and mango industry development. The project team delivered new best practice resources accessible through the revamped Australian Mangoes website, a wide range of extension activities such as roadshows, workshops and field days as well as weekly crop flow reports during the season. The two regionally based Industry Development Officers (IDOs) conducted on-farm dry matter testing and calibrated the industry's NIR instruments at the onset of each season.

The mango industry extension component was a collaborative effort involving the Northern Territory Department of Industry, Tourism and Trade (NT DITT), Queensland Department of Agriculture and Fisheries (QDAF), Western Australia Department of Primary Industries and Regional Development (WA DPIRD), Central Queensland University (CQU) and the NT Farmers Association (NTFA).

Despite the COVID-19 pandemic and border restrictions, this project reached growers from all corners of Australia representing around 90% of the industry in volume. It built a more cohesive industry underpinned by trusted networks and relationships with all industry stakeholders. It successfully improved the industry's capability to export and pursue new and improved market access, and increased awareness and adoption of Hort Innovation and other organisations' R&D investments. Best management practice information is now easier to access via the resources section of the Australian Mangoes website and the industry is better prepared in the event of an exotic pest incursion. Despite growing pressure on the domestic market due to COVID-19 and the increased cost of airfreight, fruit quality was excellent, and demand remained strong.

Keywords

Australian Mango Industry Association; Australian Mangoes; Mango extension; Best management practices; fruit quality; dry matter; export; roadshows; field days; near infrared technology (NIR); online resources.

Introduction

The Australian mango industry is located predominantly in northern Australia with 95% of production coming from north of the Tropic of Capricorn. The major production regions are the Darwin and Katherine regions in the Northern Territory and Mareeba/Dimbulah and Bowen/Burdekin regions in Queensland. Smaller but significant production occurs in the Kununurra, Carnarvon and Gingin regions of Western Australia, Rockhampton and Bundaberg regions in Queensland and in northern New South Wales. Traditionally, the mango harvest season commences in late August through until February. Although there are mangoes harvested outside of this production period, 90% of production usually occurs within this time frame.

MG17000 was designed to achieve a number of the key strategic and specific outcomes listed in the 2017-2021 Mango Strategic Investment Plan (SIP). This project focussed on the following four key areas:

1. **Mango industry extension**

The 2017-2021 SIP listed *Increased R&D and extension capacity and resources supporting industry development* as one of the key outcomes and identified extension services as being insufficient, at the time, to cover the whole industry, particularly given its large geographical spread. Similarly, one of the key learnings from *MG13017 Capacity building, Information, technology and extension for the mango Industry* was the need for Industry Development Officers (IDOs) on the ground to build the Australian mango industry's capacity and facilitate the uptake of new practices and technologies. An industry manual, the "Mango Information Kit" (QDPI) was developed in 1999 to assist and promote best practice on farm but required updating to incorporate new tools, techniques and recommendations.

2. **Mango data collection**

The Australian Mango Industry is characterised by seasonal fluctuations. Delivering accurate and timely crop flow data to key industry stakeholders is critical to ensure peaks and troughs in supply can be managed efficiently and to maximise the value of the crop. Accurately forecasting the volume of production of different varieties, the quality of the fruit, and the timing of when fruit will be sent to market is important as it provides industry participants with an objective assessment of when the harvest will commence in each region and allows them to plan for the season. Forecasting is listed in the SIP 2017-2021 as one of the strategies to achieve *Outcome 2 Increased grower profitability through increased consumer demand for Australian mangoes*. This information is used by many sectors of the industry, from on farm service providers (e.g. carton manufacturers, labour hire companies) to the wholesale and retail sector. This is especially important for large retailers when planning their category management and marketing programs.

3. **Mango quality/dry matter testing**

Harvesting at the correct maturity level, as measured by dry matter (DM) content, is critical to the development of flavour in mangoes. The impact of poor flavour is a loss of consumer appeal and demand. On-farm testing utilising near infrared (NIR) technology to predict dry matter content in mangoes has been used as a measure of harvest maturity alongside other maturity indicators such as fruit size, shape and internal flesh colour. Over multiple seasons, the Australian mango industry used this non-destructive technology to assist growers in their 'decision to pick' process. However, as reported in MG17002 *On-Farm Quality testing utilising near infrared (NIR) technology*, while the number of businesses embracing the technology increased, the uptake remained relatively low due to the limited access to machines. Appointing two regionally based IDOs with their own F750 Quality Produce Meters was recommended to improve growers' access to both the technology and professional support and allow them to move to evidence-based, block by block harvest plans.

4. **Mango industry development**

The Australian mango industry has strengthened its international reputation as a high-quality mango producer and strong demand for high-quality fresh mangoes worldwide presents a growing opportunity. However, export volume remains low (around 12% of total production). One of the barriers to increase the industry's export volume is the complexity of our key markets' phytosanitary requirements. Activities should be undertaken to develop the Australian mango industry's export capability, to take a leadership role in exports and to cultivate a more export-oriented culture.

Gaining access into new markets will provide the Australian mango industry with opportunities as well as alternatives in building the Australian mango business. It is a long-term endeavour and will prepare the industry for any adverse changes to the current domestic situation i.e. oversupply in the domestic market, decrease in domestic prices, etc.

As stated in the SIP 2017-2021, one of the mango industry's weaknesses is our lack of biosecurity preparedness for exotic incursions. In light of recent Australian produce biosecurity issues, the industry needs to assist mango growers to be fully prepared through awareness and education.

Methodology

The project focussed on four key areas; extension activities and development of best practice resources; crop flow reporting with information on volumes of mangoes forecasted and dispatched; on-farm dry matter testing and Felix Produce Quality Meters calibration; and industry development activities to improve market access and biosecurity preparedness.

The project targeted mainly Australian mango growers (levy payers) but the project team also worked closely with the federal and state government departments, researchers, retailers, wholesalers, and regional grower organisations.

Mango industry extension (R&D)

Two Industry Development Officers were appointed at the beginning of the project and were the cornerstone of this project delivery strategy. They are regionally based in Darwin and North Queensland and have successfully built trusted networks and fostered strong relationships, improving the industry's cohesion and resilience. This project partly funded these two new roles as well as the Industry Development Manager (IDM) position.

In collaboration with industry partners NT DITT, WA DPIRD and QDAF, the development of an updated Best Practice Resource (BPR) for mangoes has commenced using lessons learned from other industry BPR packages such as Bananas and Avocados.

At the beginning of the project, an evaluation panel, which consisted of the project partners, Hort Innovation, growers, a retailer, a wholesaler and Plant Health Australia, selected the three Best Practice Resource topics to run concurrently over the length of the project:

- Orchard management (including canopy management, nutrition and irrigation)
- Harvest practices (including pest and disease management and crop forecasting)
- Temperature management (throughout the supply chain)

Australian Mangoes and its project partners have developed a wide range of resources and delivered events to increase growers' knowledge, attitude, skills and aspiration and facilitate practice change in these three key topic areas.

The Australian Mangoes website was updated to include a best practice resource section and become the one stop shop for industry stakeholders and new entrants to the industry looking for recommended production and postharvest practices.

All the resources developed as part of this project are available (or will be available shortly) on the AMIA website and listed under Outputs. Vietnamese growers make up approximately 10% of the mango producers in Australia and reside mainly in and around the Darwin region. Therefore, some of these resources have been or are currently being translated into Vietnamese.

The IDM and IDOs facilitated a wide range of face-to-face extension activities including:

- Workshops and field days related to the BPR topics to demonstrate and extend R&D findings and practically demonstrate benefits and methods of implementation.
- One pre-season roadshow per region each season (Darwin, Katherine, Kununurra, Mareeba/Dimbulah, Burdekin, Bowen, Carnarvon, Rockhampton, Bundaberg and Gingin), to bring all industry stakeholders together and to inform participants of any changes applicable to the upcoming season, report on key results from last season and communicate any relevant research prior to the season starting.
- In partnership with Escavox, the project team collectively investigated cooling temperatures of fruit from packing, through transit to ripening via the use of temperature monitoring loggers. The study was conducted over two seasons and involved growers from Queensland, Northern Territory and Western Australia.

Some face-to-face events were unable to occur due to COVID-19 restrictions. These were replaced by a series of webinars. A COVID-19 manual was also developed in 2020 and translated into Vietnamese to assist the Australian mango industry in preparing for the 2020/21 season in light of the COVID-19 pandemic. The aim of this document was to provide industry stakeholders with reputable sources of information and to use as a starting point to develop COVID-19 and health management plans.

Mango data collection (forecasting)

The current national mango forecasting system was initiated in the 2014/15 season. It is a manual system operated by the mango Industry Development Officers (IDOs). The IDOs collate individual grower's weekly estimates of dispatch volumes for each variety and class (class one or two) in 7kg tray equivalents. The information relating to individual businesses remains confidential but is aggregated by region and variety. This crop forecast is made available to growers and industry via the AMIA website and the weekly My Mango e-newsletter. As the season progresses growers are encouraged to update their forecast. Actual dispatched volumes are also collected, aggregated for each region and variety, and included in the weekly crop flow report.
The nature of the data included in our weekly crop flow report has evolved throughout the project based on feedback from industry stakeholders. The collection of class information was a new initiative within the 2019/2020 season and was conducted for Kensington Pride, R2E2, Calypso, Honey Gold and Keitt. Class information for all varieties has been collected from the 2020/21 season. A bar graph was also added for the 2019/20 season to help visualise the flow of the crop and compare it to the previous season.

In conjunction with the weekly forecast report, regional updates are provided within the weekly e-newsletter, My Mango. Updates include information on the current activities of each of the growing regions and include any notable changes in weather or production. In regions where an IDO is not currently present, communication is made with growers from that region to ensure the latest and relevant information is included.

Mango quality/dry matter testing

The IDOs undertook field maturity testing using NIR technology (Felix Produce Quality Meters) to support growers with their decision to pick process. Due to COVID-19 and WA border restrictions, AMIA has coordinated local consultants to undertake dry matter testing for our growers where possible, using AMIA's NIR instruments and providing all necessary support when needed. Detailed methodology can be found in Appendix 1.

The IDOs and IDM delivered information on the appropriateness of NIR technology for determining mango maturity across variety, region and production practice and ensured that growers were aware of quality standards and other maturity indicators.

The Felix Produce Quality Meters required calibration each season. A good predictive model should cover a wide variety of sample types and compositional values (cultivar, growing condition, management practices and level of ripeness) That is why, with assistance from Central Queensland University, the IDOs calibrated the increasing number of mango industry Felix Produce Quality Meters for the appropriate varieties at the onset of each season. This included instruments from AMIA, growers, government departments and commercial entities including some new F751 instruments. Detailed methodology can be found in Appendix 2.

Mango industry development

- Market export

As part of this project, the IDM facilitated communication and liaised with the Department of Agriculture, Water and the Environment (DAWE) on behalf of industry. The industry focus has been on gaining access to new markets, improving current protocols and developing existing markets. Holding export workshops, webinars and one-on-one discussions provided key industry participants (growers, exporters, researchers, Federal, State and Territory Government staff) with a chance to openly discuss challenges and opportunities for the development of the export markets for fresh Australian mangoes. It also led to an increased awareness and a greater understanding of the key steps to export to our protocol markets.

The IDM coordinated, reviewed and collated export applications from growers willing to export to protocol markets. The IDM and IDOs assisted crop monitors and growers with crop monitor training and ensured the online training packages remained up to date. Resources were developed to assist growers and exporters with understanding the requirements of key markets. The IDM also acted as the key contact for enquiries on export with regards to protocols, workplans, markets and phytosanitary issues.

- Mango biosecurity

The IDM represented the mango industry at regular Plant Health Australia (PHA) meetings and was involved in the development of the mango industry biosecurity plan. The IDM also represented the Industry on relevant meetings of the Consultative Committee on Exotic Plant Pests and Scientific Advisory Panels as required when exotic incursions occurred.

Communication

Some of the key communications channels used as part of this project were supported by the MG17004 *National Mango Industry Communication Program.*

The industry website www.industry.mangoes.net.au provides a platform to host information and is accessible to all key industry stakeholders. A key deliverable of this project, working alongside the MG17004 project, was to refine the industry website www.industry.mangoes.net.au, primarily to make best practice resources easier to search for.

Results and discussion

Mango industry extension (R&D)

- Industry Development Officers

During the life of the project, the IDOs and IDM have built a trusted network with mango growers across all growing regions in Australia. Farm visits are key to develop and maintain strong individual relationships with growers and share industry updates through one-on-one interactions, which ultimately supports the industry's cohesion and resilience. Results from the last grower survey (see Appendix 3) have shown that 62% of respondents have agreed or strongly agreed that their engagement with the broader industry has increased through their interactions with AMIA.

The MG17004 feedback survey included a question for respondents to rate activities based on the value they brought to their business on a scale from 5 (very good) to 1 (very poor). 82% of respondents have responded either with 4 (good) or 5 (very good) to having an IDM and two regionally based IDOs (Appendix 4).

The IDOs have conducted 161 farm visits over the 2021/22 season, and a total of 1,035 farm visits over the past four seasons across all mango growing regions. A summary of the farm visits for the 2021/22 season can be found in the list of outputs (Appendix 5) and a summary of all farm visits for the past four seasons can be provided upon request. In regions were the IDOs are based, farm visits over the 2021/22 season have covered between 80% and 95% of the industry (in volume). While farm visits in WA were not possible during the past season due to COVID-19 border restrictions, and travel was limited to SEQ and Northern NSW, the IDOs have maintained regular phone contact with growers in these regions throughout the season. Farm visits were completed both in and out of season. In season visits included NIR maturity testing and sharing general industry information with growers. During out of season visits, post-season surveys were conducted to understand the challenges and opportunities faced by growers and identify the barriers to adoption of best practices. This allowed the project team to understand what is happening at the grassroots level and filter the information back to Hort Innovation and other industry organisations. The feedback is also used to update AMIA's strategy and tailor future events to growers' needs.

The IDOs and the IDM have become the key point of contact for the industry and act as a liaison between industry, government, research bodies and private organisations. The IDM and IDOs respond to industry enquiries from all industry stakeholders and facilitate communication between the different parties, ensuring the delivery of consistent and up to date advice.

- Mango pre-season roadshows and webinars

IDOs delivered 30 face-to-face pre-season roadshows in the ten key mango growing regions. A detailed list of all roadshows and webinars can be found in the list of outputs (Appendix 5).

Roadshows continue to be the preferred method of grower engagement. According to the grower survey (Appendix 3), the most strongly agreed statement was that "AMIA Roadshows provide industry updates relevant to me". Feedback provided from growers state that roadshows provide an opportunity to be updated on multiple topics from different sources in one day, as well as an opportunity to connect with other mango growers. A frequent request from growers is to ensure the CEO is present to maximise grower engagement, and to ensure topics are updated regularly for relevancy. Overall, roadshows usually engage about 65% to 85% of the industry by volume.

Due to covid-19 restrictions, some face-to-face roadshows had to be cancelled and were replaced by topic-based webinars. Webinars are a great tool to raise awareness and increase knowledge to a degree on topics of national relevance. However, face-to-face interactions are key to build trust, improve skills and facilitate adoption of new practices or technologies.

- Field days, workshops and grower tours

IDOs facilitated 12 field days/grower tours throughout the life of the project to build growers knowledge and skills in a wide range of topics.

The Water Use Efficiency Field Days were a collaboration between NTDITT, QDAF and AMIA. They enlisted Irrigation Australia to develop a customized field day, workshop, and trade exhibition in line with the irrigation BPR topic. These days were held during the 2020 off-season and involved a practical component on growers' orchards. Growers were not put off by the fee and it may have ensured that they turned up. Growers were definitely attracted by the trade show, some did not attend the event but simply came to see the trade show. The participation rate was high, having Irrigation Australia involved allowed us to make it a very technical workshop and gave added incentive to growers. The majority of participants of the irrigation workshop related an increased understanding of the topic in question. Furthermore, nearly half of respondents identified changes that they would make or investigate as a result of the information (see survey results in Appendix 6).

The grower tours included:

- VHT facility tours in both Darwin and Mutchilba,
- Processing facility in Gin Gin (QLD),
- Tours of the State and Territory Departments research stations and Central Queensland University,
- Tours of growers' orchard
- Tours of the Brisbane wholesale market

A detailed list of events can be found in Appendix 5.

Attending field days is the most popular approach for growers to develop their understanding and skills, with 83% and 90% of growers choosing this option in the two grower surveys conducted during the life of the project (Appendix 3 and 7).

- Temperature monitoring throughout the supply chain

During the 2019-20 and 2020-21 seasons AMIA worked with fresh food tracking service, Escavox, and 30 growers across the country to track and assess their fruit from packhouse to ripening. 182 domestic tracks were completed across the two seasons. A key discovery from the project was that 43% of fruit tracks did not leave the packhouse in an ideal temperature range, impacting fruit quality and having a knock-on effect for the entire cold chain. Precooled fruit has an 87% cold chain compliance for the entire journey vs. only 56% for non-cooled fruit. Detailed results can be found in Appendix 8.

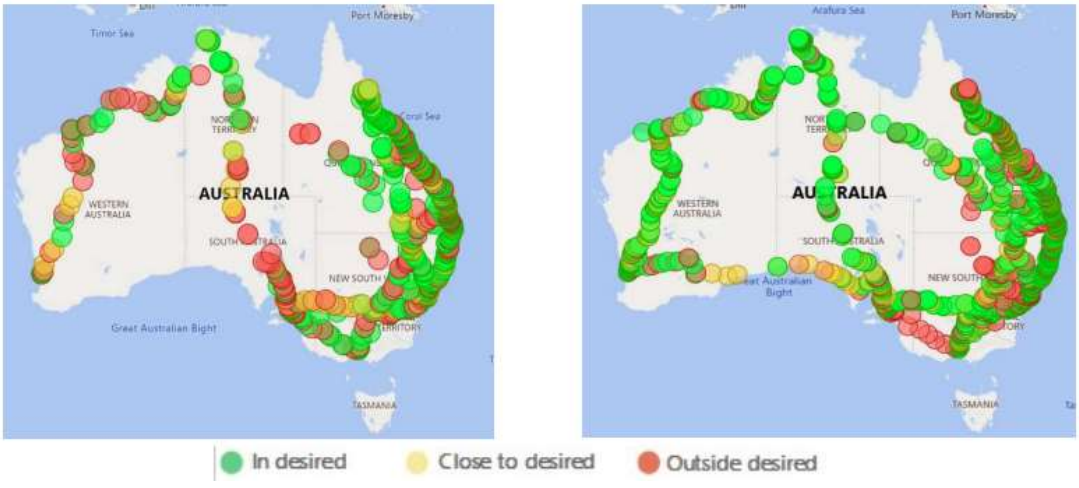


Figure 1. Heat maps of the 2019-20 season (left) and the 2020-21 season (right).

As per **Figure 1**, there were reduced temperature issues in the 2020-21 season. Cold chain compliance improved overall between the two seasons, with 77 tracks meeting compliance in 2019-20 while 102 tracks met compliance in 2020-21. When participating growers were asked to rate their confidence in their supply chains' performance before and after the project, a demonstrated increase in confidence was found. As seen in the Escavox survey results (Appendix 9), before the project growers only rated their supply chain performance as 2.83 (from 1 to 5, 1 being very poor and 5 being excellent). However, after their participation, this increased to 3.50.

- New best management practices resources

New resources were developed and reviewed by all the project partners and a list is available in the Outputs section below. These resources are available through the Australian Mangoes website.

The following resources have been or are currently being translated into Vietnamese:

- COVID-19 manual
- Resin Canal Discolouration factsheet
- Nutrition Manual
- Harvest Timing factsheet

Crop flow reporting

The Australian Mango Industry has continued to accurately forecast the volume of production of different varieties, the quality of the fruit, and the timing of when fruit will be sent to market through engagement with growers representing 86% of industry production (see Table 1). Across all regions in Australia, between 74 and 81 businesses have been involved in the AMIA crop forecasting each year for the past four seasons.

Over the past four seasons, the volumes forecasted one week out were on average 10% higher or lower than actual dispatches the following week. Figure 2 compares the weekly forecasts with actual dispatch data to illustrate national forecast accuracy over the 2020/21 season.

Table 1. Actuals vs Levy data for the past seasons ('000s 7kg eq. trays)

	Actuals	Levy data	% Actuals vs Levy
2017/18	8,956	11,996	75%
2018/19	9,459	10,958	86%
2019/20	8,899	10,702	83%
2020/21	7,091	8,200	86%
2021/22	7,972	-	-

Note: Levy data for the 2021/22 season is yet to be released.

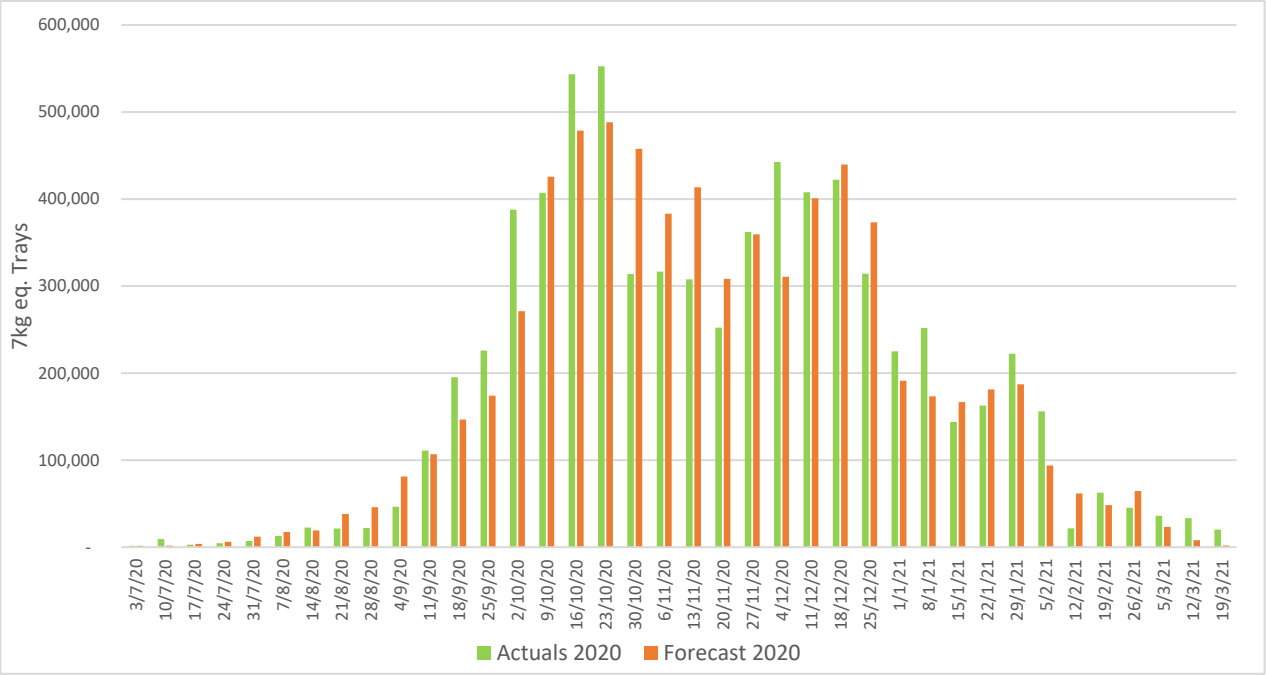


Figure 2. Comparison of forecast volumes one week out with weekly dispatch data (2020/2021).

The process, design and data were reviewed and updated on annual basis. The report has evolved throughout the life of the project and following feedback from industry stakeholders, the split between Class 1 and Class 2 was added in 2019. The additional information allows growers to make an informed decision as to whether or not it is worth sending Class 2 fruit into the market. A graph showing the weekly volumes and comparing it to the previous season was also added in 2019 (see Appendix 10). It is our third most visited page after our homepage (12,066) and the market price report (4,346) with 3,388 page views over the past 12 months.

Crop forecasting provided information on fruit volumes that are expected to come into the supply chain as the season progresses and helped managing periods of under- and oversupply of product coming into the market. All parts of the industry benefited from crop forecasting information, including:

- Growers to prepare for harvest, including timing of picker and packer employment and timing of harvest; knowing proportions of Class 1 and Class 2 fruit sent to market; knowing what is happening in other regions and if there are overlaps; overall helping growers with decision making as the season progresses
- Retailers to plan marketing campaigns to move the fruit quickly during peak periods – to ensure quality is maintained and to maximise prices
- Harvest contractors to organise the necessary workforce
- Transporters to anticipate supply of trucks for shipping mangoes to the market
- Suppliers to anticipate stocks needed (e.g. carton manufacturers)

The ability to predict harvest timing and volumes and sharing this with retailers provides them with more confidence in the Australian mango industry. Without this accurate information, fluctuations in supply cannot be managed efficiently and grower returns may be impacted. Crop forecasts updated weekly during the season enabled the industry to work with stakeholders to develop promotions to coincide with predicted supply peaks and maximise sales potential and prices for all mango industry stakeholders.

Our regional forecasts are a key output used by the AMIA Supply Chain Engagement Manager to provide accurate information to retailers. As an example, Metcash IGA uses the crop forecast published every week by AMIA for their own weekly report (Appendix 11).

At the beginning of the project, growers rated their knowledge score for crop forecasting as 5.9, ranging from 2 to 9 (with 1 being very poor and 10 being excellent). This score was the lowest scoring of all topics. The most recent grower survey shows that 50% of growers have either agreed or strongly agreed on the statement regarding their confidence in crop forecasting. However, 33% remained neutral and crop forecasting remains a challenging task for a large proportion of

growers. New technologies such as satellite imaging and machine vision are currently being developed and fine-tuned as part of a Rural R&D for profit project (ST19007) to improve forecast accuracy. As these new tools become available to growers, extension activities will be required to facilitate industry wide adoption and improve growers' confidence in forecasting.

Regional updates are provided along with the weekly crop forecast in the e-newsletter (My Mango). The IDOs provide regional updates based on face-to-face or phone conversations with growers across all growing regions in Australia. There is a weekly contact between IDOs and growers throughout the season, maintaining strong relationships including in regions where the IDOs are not currently present. Communicating regional updates keeps the industry up to date with the current activities of each growing region, and any event causing a change in production volumes. Feedback from growers, marketers, media and other related industry bodies on regional updates has been extremely positive.

Comments from the MG17004 feedback survey conducted in February 2022:

"I regularly use the My Mango newsletter for the "Crop Flow Forecasts" and production comments on the different growing regions as the base for my articles (4-6 times throughout the season). The information is clearly presented, and easily quotable. I like how they include weather and other impacts on production. The charts and tables are well presented and I am able to clearly see production data for me to understand the weekly trends. Other industries should follow the lead from AMIA and make such information publicly available to public/media."

Mango quality/dry matter testing

As a result of work conducted by AMIA and Central Queensland University (CQU), in-field assessment of fruit maturity using NIR technology has been widely adopted with 71% of the industry (by volume) using the Felix Produce Quality Meters. On-farm testing has generally been conducted by IDOs but farming businesses, having recognised the value of the technology, have begun investing in their own machines (see **Figure 3**). Woolworths have now incorporated minimum dry matter standards into their specifications and use their own and third-party machines to assess fruit maturity. It is expected that on-farm dry matter testing will transition to a fee for service type arrangement. However, despite the high adoption rate, AMIA recommends that testing continues to be provided free of charge to growers for a few more years to allow for the practice to become part of the standard operating procedure.

Over the past four seasons, a total of 32,412 NIR readings were taken on-farm across all mango growing regions (see details in the list of outputs - Appendix 5). The number of NIR readings is generally lower in Darwin and Katherine due to a number of growers having their own NIR instruments. COVID-19 and border restrictions have also been additional obstacles in providing dry matter testing services, especially in Western Australia for the 2020/21 season. AMIA has coordinated local consultants to undertake dry matter testing for our growers where possible, using AMIA's NIR instrument and providing all necessary support when needed.

50% of the respondents to the feedback survey rated the on-farm dry matter testing as being good (14%) and very good (36%) based on the value this activity had on their business. Please note that this question didn't apply to 22% of respondents (Appendix 4).

In the most recent grower survey, 57% of growers indicated that they agreed or strongly agreed to the statement "My ability to decide when to pick has improved" as a result of being involved in AMIA's activities.

Retailers' feedback has been very positive with all of them reporting consistent eating quality and texture over the past four years. However, some of them commented on the visual aspect being better some years than others which can be explained by weather conditions (e.g. wind, etc).

The on-farm dry matter testing has also allowed the IDOs to build a very strong grower network through one-on-one interactions. The time spent in the orchards with growers during the testing is priceless and allows the IDOs to engage growers, to raise awareness, build trust and understand drivers and barriers to adoption of best practices.

The IDOs, with the assistance of Central Queensland University (CQU), have conducted calibration exercises of Felix NIR instruments owned by industry stakeholders, which includes instruments owned by growers, retailers, and research bodies (CQU, NT DITT, WA DPIRD) (see **Figure 3**). Rudge Produce in Melbourne Market conducted the calibration of the wholesale market instruments with logistical and technical support from AMIA. After calibration, precision of the model is on average 0.66 (value of Standard Error of Performance).

49% of the respondents to the feedback survey rated the Felix instrument calibration as being good (14%) and very good (35%) based on the value this activity had on their business. Please note that this question didn't apply to 27% of respondents (Appendix 4).

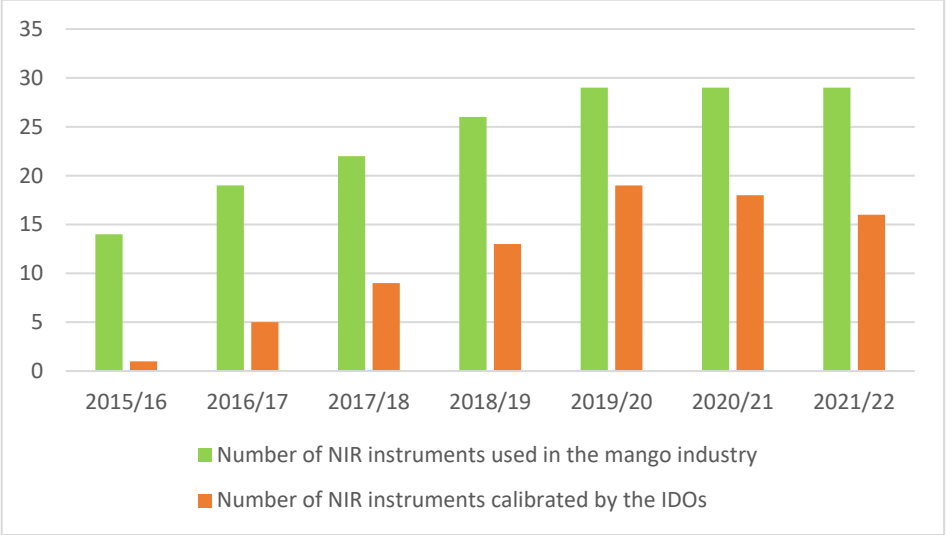


Figure 3. Number of Felix instruments used in the mango industry and calibrated by the Industry Development Officers

Some university-owned machines were calibrated by the universities themselves and others were requiring maintenance and were sent to the USA. Nearly all of the grower owned machines are calibrated by the IDOs.

It is expected that the calibration of Felix Instruments will transition to a fee for service type arrangement. However, AMIA recommends that testing continues to be provided free of charge to allow for a transition strategy to be put in place and guarantee the precision of the predictive models.

Mango industry development

- Export

The export development activities focused on the mango protocol markets (China, Korea and USA) and included:

- Communications, roadshow presentations and webinars providing growers, crop monitors and treatment facility operators with access to training and timely information on key aspects of export requirements,
- Supporting growers to complete their online applications,
- Developing export resources such as a user guide for the online registration platform and a timeline for crop monitoring to assist growers to become export ready,
- Using the Global Trade Atlas to evaluate and prepare industry reports on export trade intelligence data,
- Liaising and coordinating export registrations with DAWE.

Despite the COVID-19 pandemic and the increased cost of airfreight, the number of growers participating in export activities has increased for the past four seasons (see

Table 2). Table 3 also shows that volume increased for our key protocol markets (highlighted) despite the overall export volume being down by 44% between the 2020 and 2021 seasons.

This project contributed to developing a more export focused culture within the Australian mango industry. Over the past few seasons, some shipments were rejected due to labelling issues and Maximum Residue Limit (MRL) breaches. As part of a separate project, AMIA is collaborating with the Australian Table Grape Association and the Australian Wine Research Institute to develop and launch a Mango MRL App before the next season. Additional resources should be considered in the next mango extension and adoption project to cover product specifications, packaging, labelling, handling, etc.

Table 2. Number of businesses registered to export to protocol markets

	2018/19	2019/20	2020/21	2021/22
Number of farming businesses registered to export to protocol markets	22	28	39	39
Number of newly registered businesses (season to season)		16	10	3

Table 3. Australian mango export statistics (Source of the data: Australian Bureau of Statistics via IHS Global Trade Atlas)

Trade Partner	Unit	Primary Quantity				% Change, 2021/2020	% Change, 2021/2019
		2018	2019	2020	2021		
World	KG	7,693,509	8,220,721	7,706,924	4,319,900	-44%	-47%
New Zealand	KG	1,107,398	1,179,412	1,304,232	1,020,900	-22%	-13%
Singapore	KG	1,758,996	1,869,190	1,544,199	955,700	-38%	-49%
Hong Kong	KG	2,517,768	1,973,062	1,588,782	502,400	-68%	-75%
United Arab Emirates	KG	843,770	910,059	1,036,697	420,400	-59%	-54%
Korea, South	KG	63,034	143,140	207,669	406,100	96%	184%
China	KG	107,829	270,987	196,747	357,200	82%	32%
Qatar	KG	202,754	215,434	279,419	180,600	-35%	-16%
Canada	KG	141,402	177,856	263,798	125,400	-52%	-29%
United States	KG	63,690	64,963	73,994	122,800	66%	89%
Kuwait	KG	145,899	274,810	299,050	121,600	-59%	-56%
Saudi Arabia	KG	263,688	340,253	383,324	34,800	-91%	-90%
Oman	KG	69,632	63,704	52,028	15,200	-71%	-76%
Brunei Darussalam	KG	9,108	5,634	6,110	14,800	142%	163%
Japan	KG	34,769	23,827	15,311	12,800	-16%	-46%

- Market access

The IDM is involved in the current negotiations to improve market access to Japan and has submitted proposals to include Irradiation for China, Korea and Japan.

The IDM also provided inputs into the development of the new mango export strategy (MG21000).

- Biosecurity

The mango industry was involved in several exotic pest incursions throughout the life of the project and the IDM and/or CEO represented the industry on the Consultative Committee on Exotic Plant Pest (CCEPP). The project team used these incursions as an opportunity to increase grower awareness and knowledge about biosecurity best management practices by delivering communication, presentations at roadshows and resources.

The IDM and/or IDOs have represented AMIA on the Tropical Plant Industries Surveillance Strategy steering committee. They have also participated in the National Fruit Fly Strategy consultation and workshop and were part of the Mango Biosecurity Reference Panel which developed the new Mango Industry Biosecurity Plan and tracks the delivery against the plan.

Outputs

Table 4. Output summary

Output	Description	Detail
Two Industry Development Officers (IDOs) were appointed	IDOs are regionally based (Darwin and Cairns). They built a strong network and provided a range of services for industry such as extension, on farm dry matter testing, crop forecasting, etc	Sarah Hain and Marine Empson were appointed in August 2018. They were replaced by Paige Liebich and Celine Jordens in August 2021. Throughout the life of the project, the IDOs and IDM have become the key points of contact for any mango related enquiries. They have built strong relationships with industry stakeholders (growers, agronomists, researchers, etc) which is critical to ensure efficient communication and extension.
Crop flow reports	During the past four mango seasons, forecast and dispatch data were collected, collated and published on a weekly basis. Third most visited page on our website with 3,388 page views since the launch of our new website in March 2021.	From the 2018/19 to the 2021/22 seasons, the IDM and IDOs, with support from an external data analyst and the communication manager, have collected, collated and published a weekly crop flow report. This report is used by a wide range of industry stakeholders and is the third most visited pages on our website. Between 74 and 81 businesses are involved in the process representing about 86% of the industry (by volume). See Appendix 10.
On-farm dry matter testing	For the past four seasons, the IDOs with support from external consultants when required, have conducted on-farm dry matter testing using the Felix Produce Quality Meters.	NIR technology has been widely adopted with 71% of the industry (by volume) using the Felix Produce Quality Meters. The technology has been adopted by Woolworths, who has purchased their own Felix instruments and included dry matter into their specifications. See Appendix 5.
Felix machines calibration	The IDOs have calibrated the Felix Produce Quality Meters	For the past four seasons, the IDOs with support from Central Queensland University, have conducted calibration/validation exercises for the Industry Felix instruments. This is critical to ensure the machines predict dry matter accurately and to maintain Industry's trust in the technology. See Appendix 5.
Pre-season roadshows	The IDOs delivered 30 face-to-face pre-season roadshows in the 10 mango growing regions when COVID-19 restrictions allowed. Roadshows usually engage between 65% and 85% of the industry	Pre-season roadshows included the latest industry updates and presentations from Australian Mangoes, Hort Innovation, national retailers and other industry participants and provided valuable networking opportunities. See event details in Appendix 5.

	(volume)	
Water Use Efficiency Field Days	In collaboration with Irrigation Australia, QDAF and NTDITT, four water use efficiency field days were held on: - 23/3/21 in Darwin 39 attendees and 21 exhibitors - 25/3/21 in Katherine 48 attendees and 19 exhibitors - 27/7/21 in Bowen 26 attendees and 14 exhibitors - 30/7/21 in Mareeba 34 attendees with 19 exhibitors	These field days brought growers up to speed with the latest in irrigation technology and taught them how to improve water use efficiency, maximise crop yields and quality, resulting in saving money and water consumption. There was a theoretical component indoors and a practical one on farm where growers could test and troubleshoot irrigation systems. The participation rate was high, having Irrigation Australia involved allowed us to make it a very technical workshop and gave added incentive to growers. The majority of participants related an increased understanding of the topic in question. Furthermore, nearly half of respondents identified changes that they would make or investigate as a result of the information (see field day survey results – Appendix 6)
Field days and grower tours	IDM and IDOs delivered eight field days and grower tours	These events were designed to increase industry awareness and knowledge around a wide range of topics aligned to the key priority areas. See event details Appendix 5.
Webinars	The project team delivered 12 webinars to update growers on a wide range of topics when face-to-face events could not be held due to COVID-19 restrictions.	Webinars are a great tool to raise awareness and increase knowledge on topics of national relevance. However, face-to-face interactions are key to build trust, improve skills and facilitate adoption of new practices or technologies. In the last grower survey (Appendix 3), 90% of respondents chose “attending field days” as a preferred method for developing understanding and skills, and 31% of respondents chose “webinars and online trainings” (multiple choices available). The list of webinars can be found in Appendix 5.
Farm visits	The IDOs have conducted 161 farm visits over the past season, and a total of 1035 farm visits over the past four seasons.	Details of the farm visits conducted over the 2021/22 season is available in Appendix 5. While farm visits in some regions was limited or not possible due to COVID-19 border restrictions, the IDOs have maintained regular phone contact with growers in these regions.
Resources	QDAF and NTDITT have developed resources for the topic areas which had been prioritised by the Management team at the start of the project	These resources have been reviewed by QDAF, NTDITT and WADPIRD to ensure regional specificities were included. They have also been reviewed by AMIA and Hort Innovation. These resources are included in the new Resource library in the AMIA website. A list of all the resources is provided in Appendix 12.
Articles	The project team and partners submitted articles for publication	These articles provided industry updates on relevant and timely matters.

	into our quarterly magasine MangoMatters, eNewsletters MyMango and The Slice and AMIA website.	Example: Our article on the Mango Shoot Looper – Current management options was accessed 654 times.
Case studies	Two case studies were developed as part of the two-year trial, monitoring temperatures throughout the supply chain.	These are yet to be approved by all parties. Once finalised, they will feature in our Mango Matters magazine and will be uploaded onto the resource section of our website. Draft can be found in Appendix 13.

Outcomes

The key outcomes of this project are listed in the table below.

Table 5. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Stronger industry cohesion underpinned by trusted networks and relationships with all industry stakeholders	Outcome 3. Increased R&D and extension capacity and resources supporting industry development	The appointment of two highly capable and regionally based IDOs has allowed to more effectively engage with mango growers and local industry stakeholders (agronomists, grower organisations, etc) and built a more united industry. The direct involvement of NTDITT, QDAF and WADPRID has allowed for a more effective collaboration with state and territory departments.	Event attendance, grower engagement and feedback, number of farm visits, responses to individual event surveys, stakeholder responses to project surveys
Increased industry capability in delivering effective on the ground extension activities tailored to grower needs in all regions.	Outcome 3. Increased R&D and extension capacity and resources supporting industry development	The appointment of two highly capable and regionally based IDOs has allowed to more effectively engage with mango growers and local industry stakeholders to deliver extension activities and understand current needs and barriers to adoption.	Grower engagement, number of farm visits, stakeholder responses to project surveys
Increased capability of the industry to evaluate quality in a non-destructive and objective way enabling more consistent fruit quality to be supplied to the market.	Outcome 2. Increased grower profitability through increased consumer demand for Australian mangoes	The project contributed to consistently deliver a high-quality eating mango experience.	Retailer and wholesaler feedback, responses to project surveys
Increased grower confidence, knowledge and understanding of: - temperature management - nutrition management - canopy management - irrigation - yield estimation and	Outcome 1. Increased industry productivity through increased yields and reduced costs per hectare	Development and publication of best practice resources. Roadshows, field days and grower tours delivered practical information to mango growers.	Website visits and stakeholder responses to project surveys, grower engagement and feedback

mapping - value add opportunities - export opportunities - pest and disease management			
Increased grower skills and adoption of best management practices in the following areas: - temperature management - irrigation	Outcome 1. Increased industry productivity through increased yields and reduced costs per hectare	Field days and industry trials enabled growers to improve their skills, test new technologies and ultimately tweak or adopt new management practices resulting in better water use efficiency (reducing cost of production) and providing consistent fruit quality.	Stakeholder responses to project surveys and case studies
Better informed industry as a result of our weekly crop flow reporting (volumes of mangoes dispatched and forecast to be supplied)	Outcome 2. Increased grower profitability through increased consumer demand for Australian mangoes	The project team delivered accurate crop forecasts of varietal volumes and flow across the season which allowed for everyone across the supply chain to be better prepared and maximise the value of the crop.	Website visits, stakeholder responses to project surveys, consistent use of information by retailers and media
Better informed production sector and supply chain with confidence to participate in export markets	Outcome 2. Increased grower profitability through increased consumer demand for Australian mangoes	The project team facilitated export registration to protocol markets, delivered information session and developed resources to ensure growers are aware of the opportunities and become export ready.	Number of growers registered to export to protocol markets, volume of exported fruit
Improved access to best practice information by all sectors of the supply chain through the resources section of the Australian Mangoes website	Outcome 3. Increased R&D and extension capacity and resources supporting industry development	The Australian Mangoes website was updated to include a best practice resources section and become the one stop shop for industry stakeholders and new entrants looking for recommended production and postharvest practices.	Website visits, stakeholder responses to project surveys
Increased industry's biosecurity preparedness and capability	Outcome 4. Improved industry sustainability and management of risks	The IDM represented the mango industry at regular Plant Health Australia (PHA) meetings and was involved in the development of the mango industry biosecurity plan. The IDM also represented	New biosecurity plan, meeting minutes, biosecurity articles and presentations, stakeholder responses to project surveys

		the Industry on relevant meetings of the Consultative Committee on Exotic Plant Pests and Scientific Advisory Panels as required when exotic incursions occurred. The project team used these incursions as an opportunity to increase grower awareness and knowledge about biosecurity best management practices by delivering communication, presentations at roadshows and resources.	

Monitoring and evaluation

Table 6. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent has the project achieved its expected outcomes?	Stronger grower network and cohesive industry 71% of the industry adopted on-farm NIR testing 86% of the industry engaged in our crop flow reporting which is the third most viewed page. Nearly half of the attendees at our irrigation field days identified changes that they would make or investigate as a result Number of businesses registered for export protocol markets has almost doubled A large proportion of growers indicated that their confidence, knowledge and skills had increased in one or several of the following areas: - temperature management - nutrition management - canopy management - irrigation - yield estimation and mapping - value add opportunities - export opportunities - pest and disease management Comprehensive resources have been developed aligned with the priority areas identified by the BPR management team at the beginning of the project.	It is expected that on-farm NIR testing and Felix instrument calibration will transition to a fee for service type arrangement. Additional work is required to ensure that a larger proportion of the industry become export ready. Investigate new extension methodologies and further cross-industry collaboration. Best practice resources, aligned with the industry's key priority areas, should continue to be developed or updated. The new online Best Practice Resources on the AMIA website should continue to be promoted as the primary source of technical mango industry information for all stakeholders.
How relevant was the project to the needs of intended beneficiaries?	The project was very relevant and aligned with the SIP 2017-2021. 77% of survey respondents indicated that the roadshows' topics were of relevance to them The project was flexible enough to allow for resources to be developed on an as-needed basis. This allowed for a COVID-19	A project reference group (PRG) should be established at the commencement of a future project to provide guidance and oversight for the duration of the project. The PRG should consist of levy payers, Hort Innovation staff members and project partners and meet at least once a year to provide input and review the annual operational plans.

	manual and pest & disease updates and workshops to be developed when required. The partnership with the NTDITT, QDAF and WADPRID has allowed for regional differences to be incorporated into our resources and events.	
How well have intended beneficiaries been engaged in the project and to what extent were engagement processes appropriate to the target audience/s of the project?	The project team engaged with industry levy payers through a wide range of communication channels including pre-season roadshows, field days, grower tours, one-on-one farm visits, webinars, articles, etc. The overall engagement was very good as demonstrated by our crop flow reporting, farm visits, on-farm NIR testing and overall industry stakeholder feedback. However, areas of improvement have been identified.	Extension activities should include more on-farm, participatory demonstration trials, workshops and field days. Growers who have interests in demonstrating/trialling new practices are the best option to help facilitate practice improvements. Peer-to-peer learning is a successful way of engaging other growers and gives legitimacy to new ideas and innovations. A future project should aim for greater engagement of agronomists/consultants specifically in extension activities. This could take the form of agronomist information and training events, or an information network (possibly like the BAGMAN – Banana Agronomists & Managers group). In future, we might look at organising a mango or tropical fruit science forum to give researchers the opportunity to exchange and collaborate.
What efforts did the project make to improve efficiency?	On an annual basis, the project team reviewed and streamlined the processes for the following activities: - Crop forecasting and crop flow reporting - Calibration of NIR instruments - Export registration Cross industry collaboration to share experiences and learnings (i.e. meeting with AUSVEG regarding biosecurity preparedness, or with Avocados Australia to discuss their online BPR platform). Where travel was not possible, online events were held.	Future projects should strengthen cross-industry collaboration. Project team should attend networking activities/events facilitated by Hort Innovation and APEN.

Recommendations

The following is a list of recommendations from the successful completion of MG17000:

- The industry should continue to build upon the strong and trusted networks developed by the industry Development Manager and Officers through the life of this project.

- The industry should continue to support its extension assets and capability particularly the industry Development Manager and regionally based IDOs who have fostered strong industry relationships.

- The industry should keep the momentum going and continue the extension and adoption efforts, enhancing the accumulated information in the best practice resource and strengthening the relationships and capacity between growers, AMIA and project partners.

- When new mango related research projects are contracted, extension and grower outcomes should be built into the scope. It is recommended that research contracts have detailed requirements to collaborate with industry development projects such as Communications and Innovation and Adoption. This will assist with the adoption of new R&D outputs and maintain consistency across best practice resources.

Refereed scientific publications

No refereed scientific publications to report.

Intellectual property

No project IP or commercialisation to report

Acknowledgements

AMIA would like to thank all QDAF, NT DITT, WA DPIRD and CQU staff who have contributed to MG17000 over the project lifetime. We would also like to thank NT Farmers Association for providing an office space and professional support to the NT/WA IDO (Sarah Hain and Celine Jordens) and making them feel welcome.

AMIA would like to acknowledge the industry members who kindly hosted our pre-season roadshows, field days and orchard tours as well as the guest speakers who presented at our face-to-face events and webinars over the last four years. AMIA would also like to acknowledge Hort Innovation and the AMIA Board for their ongoing support and input to this very important body of work.

Finally, I would like to thank all AMIA staff past and present for their continued support and willingness to share their wealth of knowledge.

Appendices

Appendix 1 – NIR on-farm testing protocol

Appendix 2 – NIR Instrument calibration and validation methodology

Appendix 3 – Grower Survey Results – February 2022

Appendix 4 – MG17004 Stakeholder Feedback Survey Results

Appendix 5 – List of Outputs – 2018-2022

Appendix 6 – Water Use Efficiency Field Day Survey Results

Appendix 7 – Benchmark Grower Survey Results – February 2020

Appendix 8 – Escavox Final Report

Appendix 9 – Escavox Survey Results

Appendix 10 – Crop Flow Reports – 2018-2022

CONFIDENTIAL Appendix 11 –Metcash Example of Crop Flow Use

Appendix 12 – List of Resources – 2018-2022

CONFIDENTIAL Appendix 13 – Supply chain temperature management – Case Studies

Using the Felix F-750 Produce Quality Meter

Guide for Users

Introduction

Consumer research identified that consumer satisfaction is closely aligned with sweetness of ripe mangoes measured as brix of the fruit flesh when ripe and to fruit dry matter (DM) at harvest. Once a mango is harvested, there is minimal change in its DM. The DM represents carbohydrate levels (starch and sugar) in the mango. It is an indicator of physiological ad harvest maturity. The DM of a hard green mango is well correlated with the brix of a ripe fruit and brix is a determinant of eating quality

The DM% is the dried weight of a sample of mango flesh divided by the wet weight and multiplied by 100% to bring it to a percentage. This is the % DM. Traditionally DM is calculated by physically sampling a mango and comparing the weight of the flesh when sampled to that of the dry weight, once all of the water is removed from the flesh, using an oven or dehydrator.

The development of near infrared (NIR) technology to measure dry matter means that mangoes can be assessed for dry matter while still on the tree. This non-destructive sampling technique means that many mangoes can be sampled efficiently and minimise the chance of immature fruit being harvested.

How the Felix F-750 Produce Quality Meter Works

The Felix F-750 Produce Quality Meter uses near-infrared (NIR) spectroscopy to estimate dry matter. Working like a high-powered flashlight, the F-750 sends particles of light into the mango, then measures the NIR light interactance with molecular components inside of the mango to quantify the dry matter.

This guide has been developed to assist growers and other users to understand how to use the Felix F-750 Produce Quality Meter to measure dry matter in mangoes and get the best performance from the meter.

This guide aims to minimise inaccuracies and ensure representative data is collected, so that growers have an insight into a block or consignment's average reading. Those using the meter should consider the individual mango orchard and resources (e.g. time) available when using this guide.

This guide has been developed in association Central Queensland University and Felix Instruments Inc.

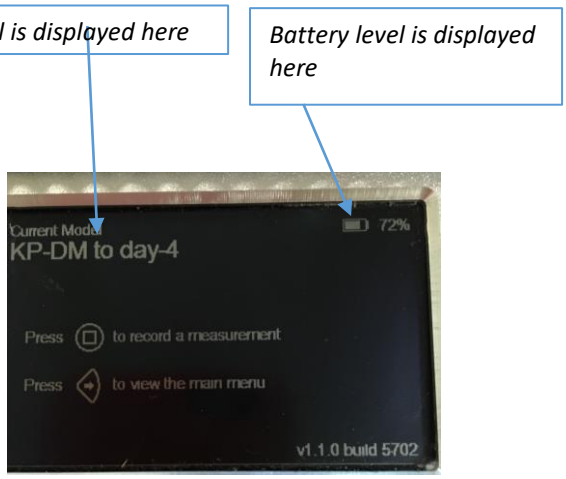
Note – Each meter should be calibrated for each variety on which it is to be used. Do not attempt to use it on varieties for which it has not specifically been calibrated. Each meter should have its calibration checked prior to the season commencing.

Using the Felix F-750 Produce Quality Meter

1. Setting up the machine:

   a. Turn on the machine via the small green power button located on the front of the machine (ensure this is turned on sometime before use to allow enough time for the GPS to be enabled)

   b. Ensure the battery is not lower than 15% (located in top right corner on main menu screen). If it is too low, change the battery by turning the machine off, lifting the bottom rubber cover on the machine and unscrewing the bottom left corner of the machine



The main menu display on the Felix F-750 Produce Quality Meter

   c. Select the correct model[1] for the fruit that you will be testing (all done with the right arrow button "->"). Ensure *measurement per specimen* is set to one (1) by pressing the right arrow button again and then press the down button once. Then press the right arrow button again on *measurements per specimen* and use the arrow buttons to select one (1). Press the left arrow button to go back to the previous menu. Ensure *scans to average* is set to four (4) by then using the down arrow button until you get to *scans to average*, then press the right arrow button and use the arrow buttons to select four (4)

   d. Ensure the current sample is set to one (1) prior to starting a new sample collection (e.g. 30 fruit for block one) and the lot number is set to one (1) (or the corresponding lot number you are on—if the block does not have a number i.e. if it has a name instead such as "Harry's block" it would be best to start at one (1) and take a note separately of what the block is called) to do this:

      i. Press the right arrow button from the main menu

      ii. Press the down arrow button until you get to *setup instrument*

      iii. Press the right arrow button once, then again on *lot and sample*

      iv. Select *current sample #* with the right arrow button and adjust the sample number back to one (1) using the arrow buttons

      v. Press the left arrow button to go back to the previous menu and use the down arrow button to select *current lot #*. Follow step iv again to select the lot number

[1] E.g. Kensington Pride model, R2E2 model, Calypso model, Honey Gold model

vi. Press the left arrow button to go back to the previous menu. Press it again to go back to the previous menu. Press the down button once to *record prefix*. Press the right arrow button once and use the arrow buttons to record a name. This is important for people who are visiting several orchards or blocks on the one day

vii. Press the left arrow button until you get back to the main menu. Your machine is now ready to conduct scanning

viii. Don't forget to change lot numbers if you are conducting scans on more than one block, and to change the sample number back to one (1) on each block. Don't forget to change the prefix also, each time you visit a new farm.

2. When scanning the fruit, bring the scan area (at the top of the machine) to the middle of the cheek and press the small black button (that has a square in the middle) once. Be sure to hold it close to the fruit for a few seconds while the scan completes and remember to avoid blemishes, spots, sunburned fruit etc.

Be sure to hold the Felix F-750 Produce Quality Meter in the middle of the cheek

Selection of fruit for sampling

1. Ensure fruit is big enough, no smaller than the size of a small orange[2]

2. Consider the following regarding flowering before conducting scans as it may be better to conduct separate sample collections:

    a. If there was a single flowering, you can conduct one sample collection (at least 30 readings) per block

    b. If there were several flowerings in the block, or on the tree, and a strip pick is planned, readings should be taken from each flowering event [3,4]

    c. If planning to do a select pick on the first flowering event, it may be best to conduct a sample collection only on the first flowering event[5]

    d. Is there any significant variations in elevation e.g. in a gully[6] (as this will affect fruit maturity).

3. Based on the above considerations select trees that are representative of the whole orchard and select trees that are central i.e. not on the ends of the rows. If time permits it is best to mark the trees and fruit that has been tested with a ribbon and to write the date and reading on the ribbon, so that the exact same fruit can be re-tested next time and readings can be compared (if needed)

4. When conducting a sample collection, do at least 30 fruit scans per block:

[2] If the fruit is too small readings will be inaccurate as the infrared light that penetrates the fruit hits the seed

[3] See step 3 for advice on fruit selection

[4] All fruit should be at least the size of a small orange as specified in step 1. If not, it may be better to wait until the second flowering event has caught up to the first flowering event. You may also need to check that the flowering events are within two weeks of each other, if not there may be too much variability and separate sample collections should be taken

[5] Once data is extracted it should be separated before sending. See an example of this in appendix one

[6] Difference in elevation may cause different maturity in fruit to the rest of the block, therefore it would be advisable to include this section of the block in the sample collection if planning a strip pick, or conducting a separate sample collection only on this area if planning to spot pick

a. Approximately five trees in each block should be tested

b. Approximately two to three fruit per tree should be tested **on both sides of the fruit (four to six scans per tree)**

c. In your sample collection ensure you are testing fruit from both the inside and outside of the tree and that you are testing fruit on both sides of the tree as well as higher and lower on the tree

Select fruit in the middle of the row, on both sides of the tree

d. If there is a lot of variation in readings, it is better to get a bigger sample size dependent on the time you have.

Note – fruit that has already been picked can be tested with the Felix F-750 Produce Quality Meter. Sample at least 30 fruit

Obtaining the data from the machine

1. After collecting your readings turn the machine off, open the rubber lid at the top, take out the SD card and insert into your computer's SD card reader:[7]

    a. Once the card is inserted the data viewer software should automatically upload; if not, open data viewer. Once open, select the file button in the top left corner, select open. Then select the files to open and select open again

    b. Select the files you wish to open in the data viewer menu and then select file, export, measurements. This will create an excel spreadsheet of your measurements. Select where you would like to save the excel file and select save

    c. Go to the location where you have saved your file and open the file. Be sure to now save the file as an **excel sheet**, rather than a CSV file, so it saves any formatting changes

    d. You can now separate out this data by block and down the bottom of each block's readings it is suggested you create a row for the average (AVERAGE), SD (STDEV)[8], maximum (MAX) and minimum (MIN). Ensure you change the decimal place to two places in column e, e.g. 15.20, and that data from column e (the dry matter readings) in the above rows is included in the excel formula e.g. =AVERAGE (E2:E9). Hit save once you have finished.

    e. Before removing the SD card from the computer open the SD card on your computer and create a folder to archive your readings. Suggested format is day, month, year e.g. 1_JAN_2017. Select the files you wish to archive and drag them into this folder.

2. Once complete ensure you safely remove the SD card from the computer (eject from computer by right clicking drive and then eject, or safely remove hardware on bottom right) and then insert it back into the Felix F-750 Produce Quality Meter. Failure to remove safely may cause the data on the SD Card to be corrupted

[7] Ensure you have first downloaded the correct data viewer software available at: https://felixinstruments.com/support/F-750/software/.
Note – this software is not available for download on Mac

[8] Standard deviation will indicate the sample size. If the standard deviation is one (1.00) and the average reading is above the minimum standard, the fruit generally should be ready to pick. If the standard deviation is more than one (1.00), it would be better to wait one to two weeks before picking the fruit to ensure the majority of the fruit tested is above the minimum standard. If your standard deviation is above two (2.00) it is suggested that another sample collection with more fruit is conducted before picking

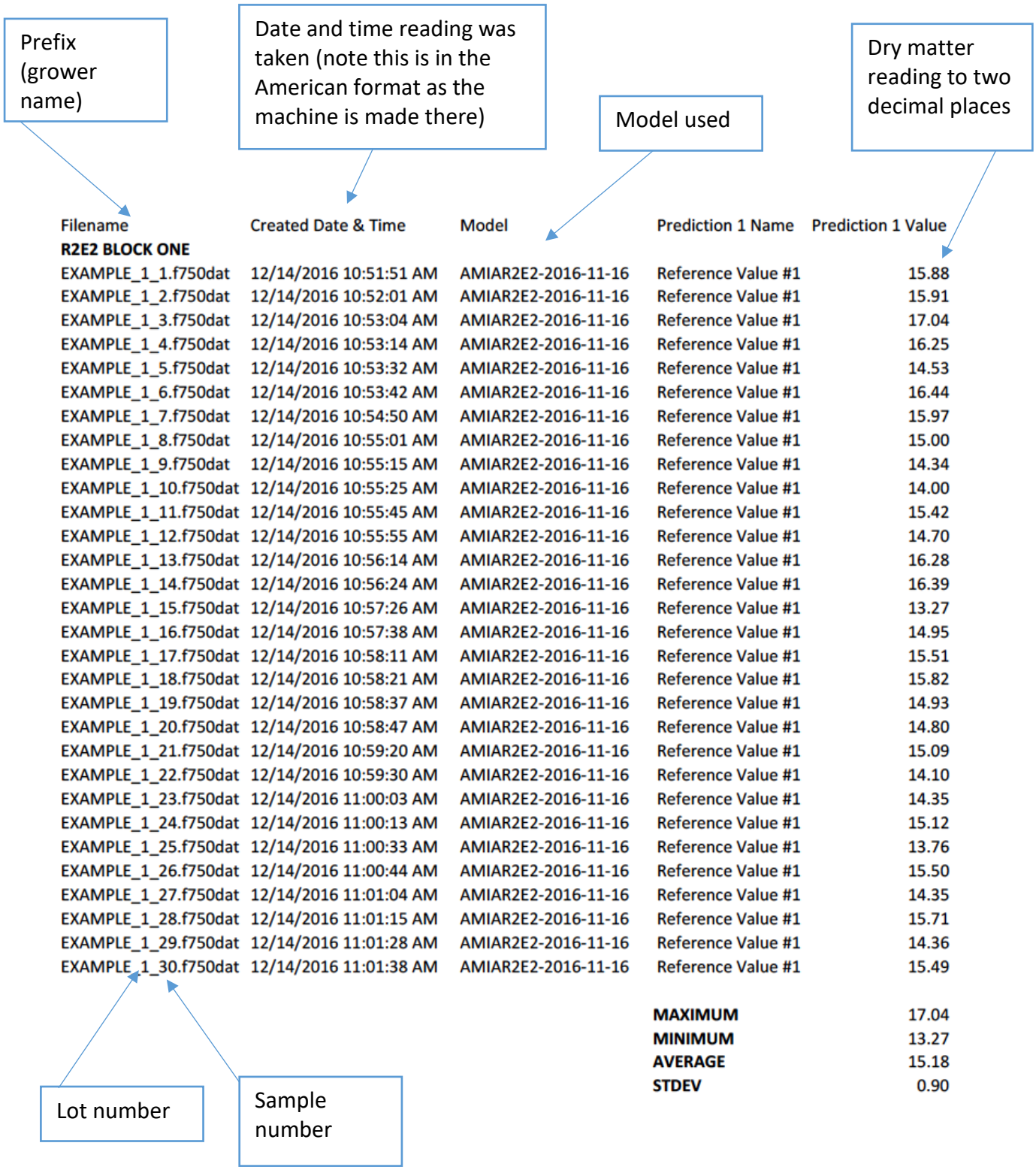
Acceptable readings

Below are the acceptable minimum industry averages for each of the main varieties. As a rough guide, if fruit is below the average DM, it will increase in DM **by 0.7 per week (NT) / 0.6 per week (QLD).**

Please note that this is only a guide, and further sampling should be undertaken before you commence harvest

Variety	**Dry Matter % DM**
Kensington Pride, Calypso, Honey Gold	**15%**
R2E2	**13%**

Appendix one – example of readings in an excel spreadsheet



Filename	Created Date & Time	Model	Prediction 1 Name	Prediction 1 Value
R2E2 BLOCK ONE				
EXAMPLE_1_1.f750dat	12/14/2016 10:51:51 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.88
EXAMPLE_1_2.f750dat	12/14/2016 10:52:01 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.91
EXAMPLE_1_3.f750dat	12/14/2016 10:53:04 AM	AMIAR2E2-2016-11-16	Reference Value #1	17.04
EXAMPLE_1_4.f750dat	12/14/2016 10:53:14 AM	AMIAR2E2-2016-11-16	Reference Value #1	16.25
EXAMPLE_1_5.f750dat	12/14/2016 10:53:32 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.53
EXAMPLE_1_6.f750dat	12/14/2016 10:53:42 AM	AMIAR2E2-2016-11-16	Reference Value #1	16.44
EXAMPLE_1_7.f750dat	12/14/2016 10:54:50 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.97
EXAMPLE_1_8.f750dat	12/14/2016 10:55:01 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.00
EXAMPLE_1_9.f750dat	12/14/2016 10:55:15 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.34
EXAMPLE_1_10.f750dat	12/14/2016 10:55:25 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.00
EXAMPLE_1_11.f750dat	12/14/2016 10:55:45 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.42
EXAMPLE_1_12.f750dat	12/14/2016 10:55:55 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.70
EXAMPLE_1_13.f750dat	12/14/2016 10:56:14 AM	AMIAR2E2-2016-11-16	Reference Value #1	16.28
EXAMPLE_1_14.f750dat	12/14/2016 10:56:24 AM	AMIAR2E2-2016-11-16	Reference Value #1	16.39
EXAMPLE_1_15.f750dat	12/14/2016 10:57:26 AM	AMIAR2E2-2016-11-16	Reference Value #1	13.27
EXAMPLE_1_16.f750dat	12/14/2016 10:57:38 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.95
EXAMPLE_1_17.f750dat	12/14/2016 10:58:11 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.51
EXAMPLE_1_18.f750dat	12/14/2016 10:58:21 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.82
EXAMPLE_1_19.f750dat	12/14/2016 10:58:37 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.93
EXAMPLE_1_20.f750dat	12/14/2016 10:58:47 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.80
EXAMPLE_1_21.f750dat	12/14/2016 10:59:20 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.09
EXAMPLE_1_22.f750dat	12/14/2016 10:59:30 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.10
EXAMPLE_1_23.f750dat	12/14/2016 11:00:03 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.35
EXAMPLE_1_24.f750dat	12/14/2016 11:00:13 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.12
EXAMPLE_1_25.f750dat	12/14/2016 11:00:33 AM	AMIAR2E2-2016-11-16	Reference Value #1	13.76
EXAMPLE_1_26.f750dat	12/14/2016 11:00:44 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.50
EXAMPLE_1_27.f750dat	12/14/2016 11:01:04 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.35
EXAMPLE_1_28.f750dat	12/14/2016 11:01:15 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.71
EXAMPLE_1_29.f750dat	12/14/2016 11:01:28 AM	AMIAR2E2-2016-11-16	Reference Value #1	14.36
EXAMPLE_1_30.f750dat	12/14/2016 11:01:38 AM	AMIAR2E2-2016-11-16	Reference Value #1	15.49
			MAXIMUM	17.04
			MINIMUM	13.27
			AVERAGE	15.18
			STDEV	0.90

Calibration and Cross-Validation of the Felix Produce Quality Meter F750 Mango Model
DAF Mareeba November 2018

Introduction

Near Infrared Spectroscopy (NIRS) provides a rapid and non-destructive means to predict mango dry matter which, in turn, can be used as an indicator of fruit maturity and potential eating quality. NIRS is an indirect analytical technique which requires calibrations. These calibrations are based on the correlations of the spectra of each sample with their known dry matter content. The results and accuracy of calibrations are then validated by using another sample set and comparing the Felix Produce Quality Meter results with those obtained by the destructive dry matter assessment. A good model for the prediction of unknown samples should cover a wide variety of sample types and compositional values (cultivar, growing condition, management practices and level of ripeness) so that the unknown sample should not be a spectral/chemical/physical "outlier" but instead should be of a similar spectral and physico-chemical composition to some of the samples used to build the model. That is why every year, AMIA and CQU source a wide range of sample sets and undertake model calibration and cross-validation. This ensures the dry matter predictions obtained with the Felix Produce Quality Meters are as accurate as possible.

It is important to note that each Felix machine has a unique spectrometer and that for the same sample, the spectra for each machine might vary slightly. A predictive model can be transferred from one device to another with a slight sacrifice in model performance. It requires a spectral correction (the difference in signal between the two spectrometers) by the means of a shared calibration. The amount of effort required for a transferred model is unique akin to the unique spectrometer and must be validated (the device must be included in a validation exercise) to assure the transfer was successful.

Materials and Methods

One of the calibration/validation exercises took place at QDAF, Mareeba on 7 and 9 November 2018. The fruit sets used were as follows:

- **20 R2E2 – Hard Green** set from Bowen which had been picked on the 6th of November.
- **20 KP – Hard Green** set from Dimbulah which had been picked on the 6th of November.
- **20 R2E2 – Ripening** set from Bowen. The fruits were picked on the 1st of November and dipped in Ethephon (1000ppm) for 1 min on the 6th of November. They were then air-dried and kept at 21°C until soft on the 9th of November.

We will focus here on two of the Felix machines included in this process, the Master machine (ending in 15006) and the AMIA North QLD machine (ending in 15014).

For each instrument, existing models from previous seasons were used to predict dry matter (DM) of R2E2 and KP fruits from the current (2018) season. The measurements were taken on both cheeks as described in the Felix produce quality meter – guide for users.

Materials:

- Cutting board
- Large knife
- Drying oven
- Small tin foil trays

- Felix corer (same diameter as the machine spectrometer – 28mm)
- Permanent marker pen
- Balance (0.001g accuracy)

Method

Preparation and DM prediction

1) Each tin foil tray was numbered from 1 to 120 and weighed (recorded as 'pp' for patty paper);
2) Each cheek was numbered, and a semi-circle was drawn to indicate the position of the spectrometer;
3) DM was predicted on each cheek using the Felix Produce Quality Meters.

Destructive DM assessment

1) Both cheeks were cut from each mango and a sample was taken from both cheeks using the Felix corer where the semi-circles were drawn. The samples were then peeled so only the flesh remained and cut to be around 1cm thick. The samples were placed into the corresponding trays.
2) Each tray was weighed (recorded as 'wet'). This process was repeated for the remaining 119 fruit.
3) All trays were placed into a drying oven pre-set at 65°C for approximately 48 hours.
4) Trays were weighed (recorded as 'dry').
5) Dry matter was calculated as follows:
   Dry Matter % = Dry weight/Wet weight x 100%
   Where:
   Dry Weight = 'dry' – 'pp'
   Wet Weight = 'wet' – 'pp'
6) The datasets were then loaded onto the F-750 Model Builder software and a linear regression was conducted providing a full statistical analysis of the model fitness.

R^2, Coefficient of Determination **-** Describes how well the data points fit the statistical model (the line of regression). Values range from 0 to 1. A 100% accurate model would have an R-Squared of 1 with all samples lying on the regression line. This statistic needs to be used with caution since it is sensitive to the sample range.

RMSEP, Root Mean Square Error of Prediction **-** This measures the average accuracy of the prediction (i.e. the difference between the true and estimated dry matter). In this instance, this statistic is a better measurement of model accuracy as it specifically describes the error in individual measurements.

Bias - This is defined as the average difference between the NIR-predicted value and the real value. A positive value means that, on average, the model is over-estimating the composition by this amount whilst a negative value represents an underestimation.

SEP, Standard Error of Prediction refers to the error term if all measurements have the bias subtracted.

Results and discussion

As you can see in Table 1, the 15014 device performed remarkably well on hard green R2E2 with a bias of only -0.14. The KP population had a large bias in all devices. For the R2E2 ripening set, the 15014 device had slight bias and the fact that the 15006 device performed well points to a bias not caused by the population but rather the instrument itself. This can be explained by the fact that the 15014 device was taken prematurely from the NT and only had calibration/transfer from hard green fruits at the start of the season. This decision was based on the fact that this device was predominantly going to be used on hard green fruits. This population was added to the mango model which should correct for this bias.

Table 1: Regression results for the two devices and three populations.

Cal	Device serial number	R^2	RMSEP	SEP	Bias
Hard Green KP	15006	0.69	1.26	0.73	1.03
	15014	0.73	1.57	0.66	1.43
Hard Green R2E2	15006	0.84	0.93	0.44	-0.82
	15014	0.89	0.41	0.38	-0.14
Ripening R2E2	15006	0.67	0.54	0.54	0.06
	15014	0.65	1.09	0.55	0.94

Reference

Using the Felix F-750 produce quality meter - guide for users.

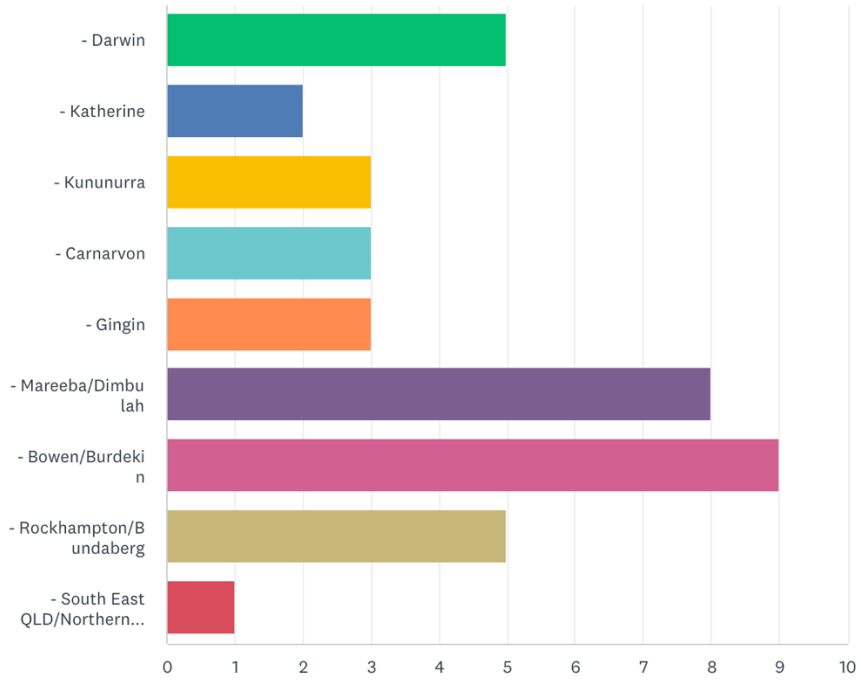
MG17000 – Grower Survey Results

The purpose of this survey was to evaluate whether grower knowledge and skills have increased as a result of being involved in any Australian Mangoes Best Practice project activities. The survey also aimed to identify key priority areas to improve crop yield and fruit quality.

It also aimed to understanding growers' learning preferences, so that the BPR team can prepare project resources which are tailored to their needs and which will be accessible through the Australian Mangoes website. A sample of 39 mango growers, covering all mango growing regions across Australia, were surveyed between January 2022 and February 2022 by the two Australian Mangoes Industry Development Officers. The surveys were conducted either face-to face, over the phone or by growers completing them independently.

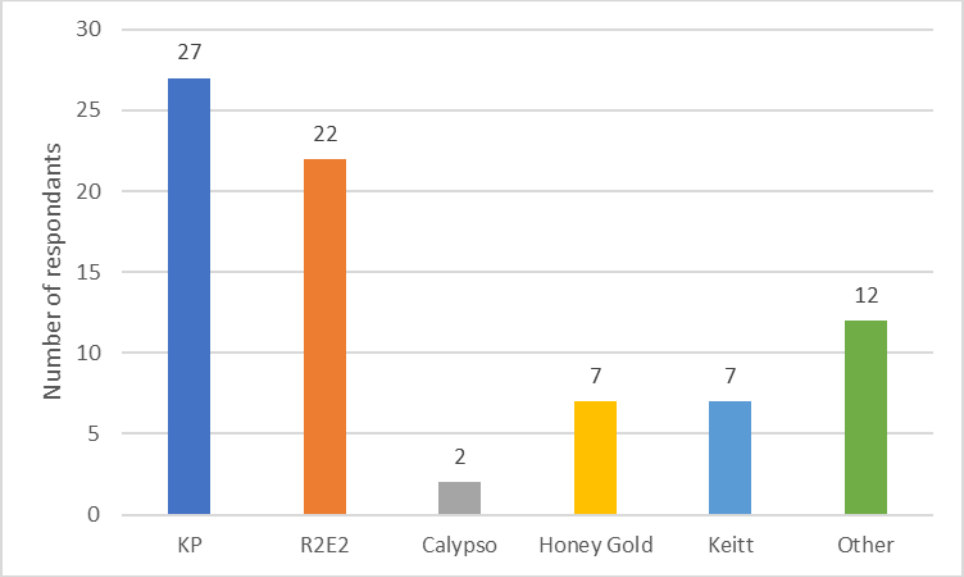
Demographics

1. Which region is your property located in?

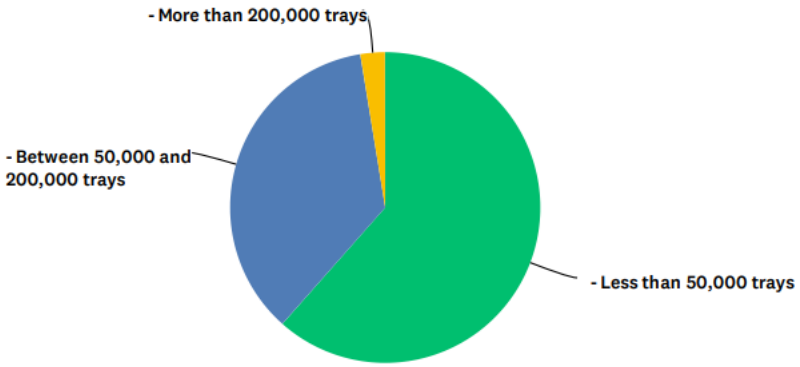


2. Orchard information – Varieties

Please note that the majority of respondents had more than one variety. "Other" includes Kent, Brooks, NMBP varieties, Keow Savoy, Nam Doc Mai and other green eating mangoes. Calypso growers usually represent larger productions with less growers across Australia. A good cross section of the industry is represented here.



3. What is the average number of trays (7kg eq) produced per year?



A majority of our respondents were smaller production growers, which is a good representation of the industry.

Summary of Q1, Q2, Q3:

A sample of 39 mango growers, covering all mango growing regions across Australia, were surveyed between January 2022 and February 2022 by the two Australian Mangoes Industry Development Officers. The surveys were conducted either face-to face, over the phone or by growers completing them independently online.

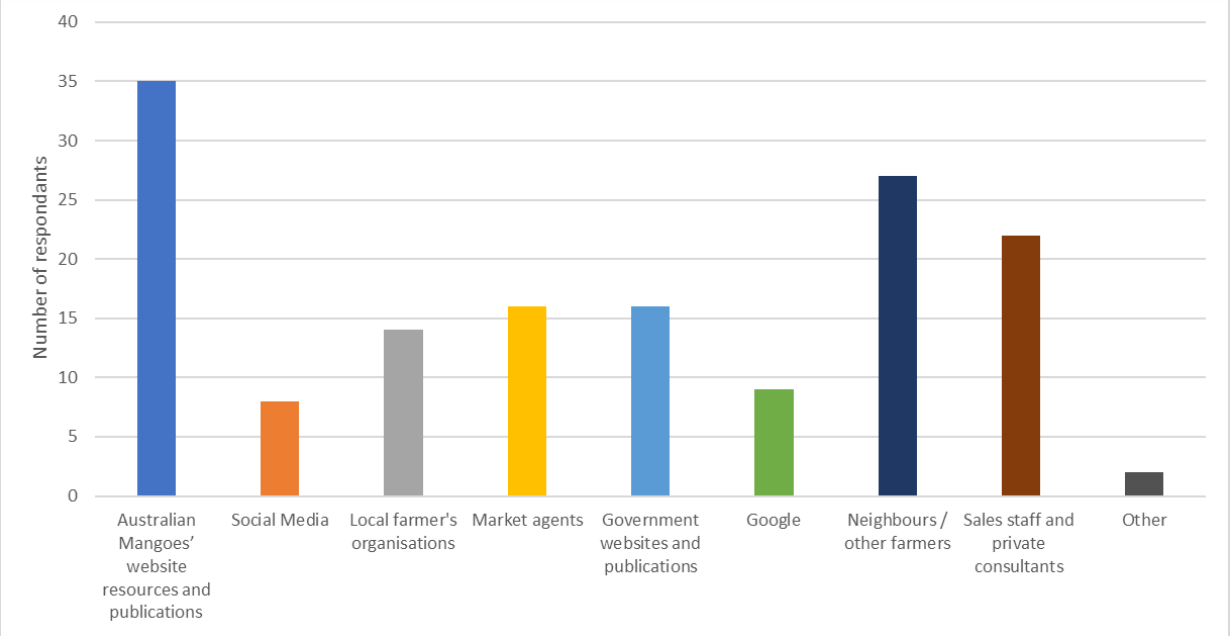
The 39 respondents of the surveys represented a good cross section of the industry in terms or growing region, varieties grown and size of their production. The majority of respondents had more than one variety. “Other” includes Kent, Brooks, NMBP varieties, Keow Savoy, Nam Doc Mai and other green eating mangoes. Calypso growers usually represent larger productions with less growers across Australia.

Learning preferences

4. Where do you seek / find out information relating to the mango industry?

Australia Mangoes' website resources and publications includes the weekly in-season newsletter My Mango, the monthly out-of-season newsletter The Slice and the quarterly magazine Mango Matters which includes more detailed articles and updates. The AMIA website also includes a range of resources available to the industry, which are updated regularly. Government websites and publications include information from the NT Department of Industry, Tourism and Trade (NT DITT) and the QLD Department of Agriculture and Forestry (QDAF). Sales staff and private consultants can include chemical companies and agronomists.

These results show that AMIA's website, resources and publications are the main resources growers utilise when seeking new information. Updates and relevant information should continue to be provided on these platforms. The figure also shows the important role that other growers and sales staff/private consultants have in providing advice to the industry. Many respondents also find out about useful information when speaking with their neighbours and other farmers, underlining the need to continue to encourage networking amongst growers through workshops, field days and AMIA's roadshows.

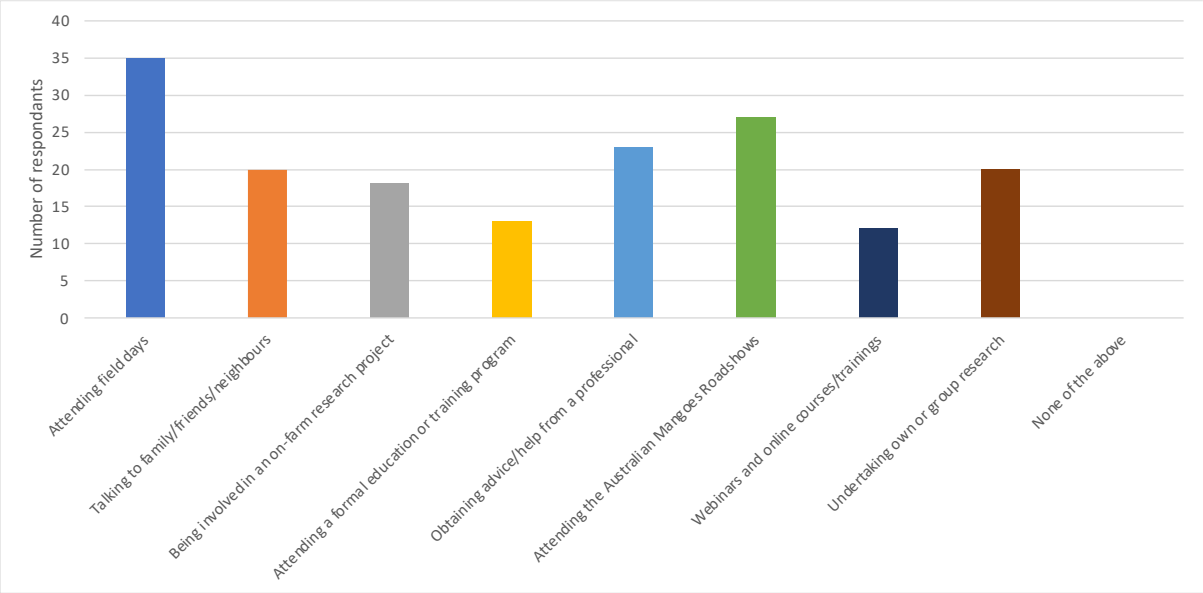


When comparing these results with the previous BPR survey, where 36 growers were surveyed between September 2019 and April 2020, the results were very similar for the top three preferences. However, "Google" was selected by 19 respondents in the last survey and only by 9 this time. This might suggest that growers are focusing their research on more centralised resources that include the Australian Mangoes website and publications.

5. What are your preferred method(s) to develop your understanding and skills?

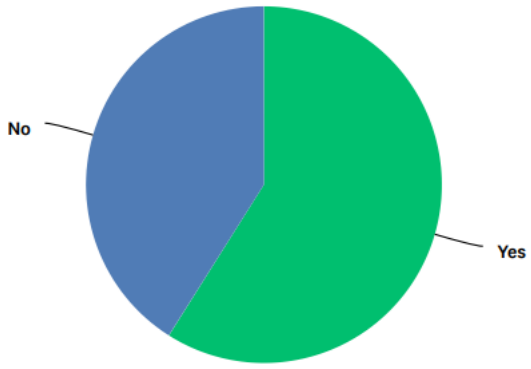
Attending field days continues to be the most popular option for growers to develop their understanding and skills, with 90% of growers choosing this option. AMIA roadshows is the second most popular option with growers, and talking to family/friends/neighbours, obtaining help from a

professional and undertaking own or group research are all popular options. This indicates that most growers (35 out of 39 respondents) value practical based learning such as observing others' on-farm practices or seeing technology/ideas in action. Apart from field days, no preferred learning method excessively stands out in the graph below, which shows that growers have different preferences when it comes to developing new skills, hence the importance to diversify our activities and resources.



6. Would you be interested in belonging to special interest group or network?

60% of growers indicated that they are interested in belonging to a special interest group or network. Some growers who stated they were not interested in this option was because they already belonged to another farming group and did not have the time or capacity to be involved in another. Growers that responded positively were usually interested in very specific topics, and did not want to invest time in hearing about topics less relevant to them. Such interest groups would also encourage networking and discussion amongst our growers, which has been identified in the questions above as a main/preferred way for growers to find out information and learn new skills.



7. If yes, what topics would you most like to learn about?

24 growers answered this question and used to generate the word cloud below and identify the most useful topics of this resource. The more frequently the word was used, the larger it is displayed.

The word cloud indicates that pests and diseases management, improving yields through crop management practices, export and marketing were topics of particular interest.

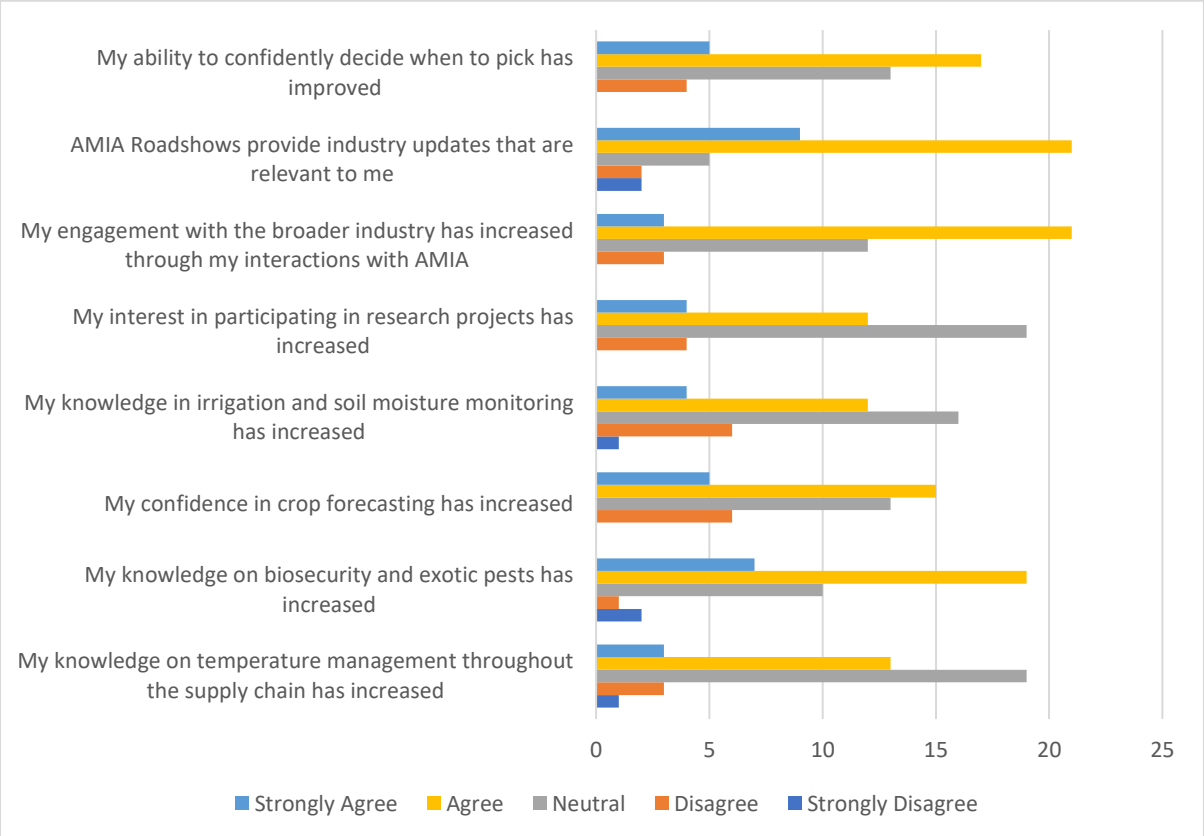
Some feedback provided:

- "Management of mango diseases, chemical best utilisation generics and alternatives, crop nourishment, pruning techniques for better yield, blower/mister nozzle setup"
- "Diseases and pests in the area. Forecast. Post-Harvest problems and ideas from other farmers. Covid Management. Labour issues."
- "Better yield, profitability, export, IPM"

We recommend that any new mango extension and adoption project further explore grower interests and opportunities to develop special interest groups.

Production practices

8. Thinking about your involvement in any AMIA's activities over the past three years (webinars, roadshows, field days, newsletters, Industry Development Officers, etc), please rate the extent to that you agree/disagree with the following statements:



Across all queries growers overall agreed with or were neutral on each statement. Growers strongly agreed or agreed most often to the below:

- AMIA Roadshows provide industry updates that are relevant to me
- My engagement with the broader industry has increased through my interactions with AMIA
- My knowledge on biosecurity and exotic pests has increased

This shows the importance for AMIA to provide valuable information and updates throughout events, workshops and roadshows by continuing to collect growers' feedback on their specific needs and topics of interest. It is important to note that the statements where growers have disagreed or strongly disagreed could represent a topic of interest to develop further in future projects.

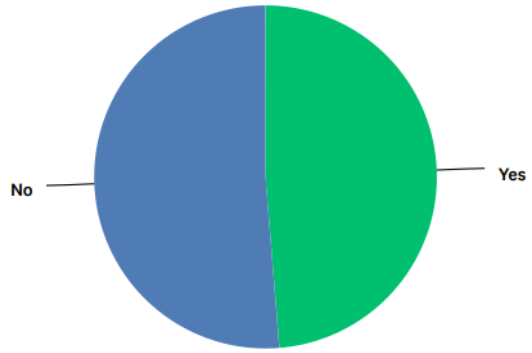
Pests and diseases were a topic of particular interest, as shown in Q7, and is also one of the most agreed statements above, as growers have noticed an improvement in their knowledge of pests and diseases through their involvement in AMIA's activities. This also underlines that it is a topic to continue to develop and provide our growers with regular updates.

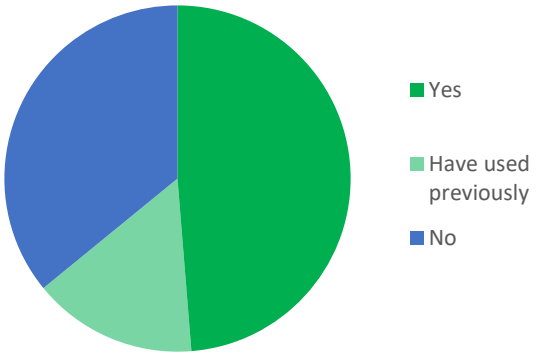
In the previous BPR survey, where 36 growers were surveyed between September 2019 and April 2020, respondents were asked to rate their knowledge and confidence on a range of topics from 1 to 10 (with 1 being very poor and 10 being excellent). The respondents' average knowledge score for pests and diseases management was then 6.8, ranging from 4 to 9. Results from the recent survey shows that the statement on pests and diseases knowledge was one of the most agreed on, and suggests that growers' knowledge on this topic has likely increased.

We note that the statement on growers' knowledge on temperature management throughout the supply chain was targeted to some growers that have participated to the Escavox project, hence the reason why a significant proportion of our respondents that haven't participated have answered "Neutral" to the statement. More details on cases studies regarding this project can be found in the Escavox report.

In the previous BPR survey conducted between September 2019 and April 2020, growers have rated their knowledge score for crop forecasting as 5.9, ranging from 2 to 9 (with 1 being very poor and 10 being excellent). This score was the lowest scoring of all topics. The most recent survey shows that a majority of growers have either agreed or remained neutral on the statement regarding their confidence in crop forecasting. New technologies such as satellite imaging and machine vision are currently being developed and fine-tuned as part of a Rural R&D for profit project (ST19007). As these new tools become available to growers, extension activities will be required to support an industry wide adoption and improve forecast confidence and accuracy.

9. Do you use NIR testing to assist in your decision to pick process?





While just under 50% of growers use the NIR technology to decide when to pick (graph 1), this represents the proportions of our respondents that consistently use and/or usually rely on NIR dry matter testing before picking. The growers who have responded "No" include growers that do not use the technology at all, as well as growers who only use the NIR results to confirm their observations on fruit shape and flesh color to assess fruit maturity (graph 2).

A large proportion of growers are confident in their ability to decide when to pick without the need of the NIR technology, especially long-term growers that have years of experience before the technology was available. However, the availability of the NIR technology remains an additional assurance to these growers that their observations are correct. The past three seasons have been drier than usual, making it easier for the fruit to reach high dry matter content. In the event of a wetter winter and spring, reaching the minimum industry dry matter standards could be more challenging and therefore it is expected that the interest in and need for on-farm dry matter testing would increase.

Moreover, large retailers such as Woolworth have included minimum dry matter content into their specifications and use NIR instruments to assess the fruit at reception. Wholesalers have also been requesting on-farm NIR results from growers.

10. If yes, have you noticed a difference in fruit quality, returns? Please describe.

21 growers responded to this question, with 13 growers indicating that they did not notice an improvement in fruit quality or returns. The most common reason for the no answer from growers was that they already picked mature and high-quality fruit before NIR was available, and they only use NIR for confirmation of their methods.

Of the growers that stated they had seen changes, an improvement in fruit quality was the most common reason stated.

Other responses include:

- "No. NIR gun is one of the tools to assist with fruit maturity in picking time. We have already picked when our fruit is mature even before the NIR gun. We have always been doing the right thing."
- "Only done it this year. Made no difference to market acceptance or price."
- "Fruit quality and returns. A great tool, use 80% of the tool and 20% experience."

- “Quality of fruit being presented to the consumer has improved considerably since NIR was introduced.”
- "I would have lost fruit if not using the NIR gun - I did not think they were ready."

11. If you do not use NIR testing, please explain why not?

22 growers responded to this question, with the most common response being that their own experience was enough to determine when the best time to pick is. Other responses include:

- “Machine not available, and I don't find the results very reliable”
- “Being an old fella, I know from experience how developed the fruit needs to be before picking”
- “Our biggest indicators have been customer and consumer feedback, and our own shelf-life tests.”

A lot of experienced growers are confident in their ability to decide when to pick without the need of the NIR technology, especially when they have years of experience in the industry and are used to work without the NIR technology (and before it was available). Over the past two seasons, COVID-19 and border restrictions have also been additional obstacles in providing dry matter testing services, especially in Western Australia. In such circumstances, AMIA has coordinated local consultants to undertake dry matter testing for our growers where possible, using AMIA’s NIR instrument and providing all necessary support when needed.

12. What are the current barriers preventing you from increasing your crop yield? Please describe.

37 growers answered this question and used to generate the word cloud below and identify the most useful topics. The more frequently the word was used, the larger it is displayed.

Weather and climatic challenges are the most common barrier for growers in improving their crop yield across all regions, with challenges at flowering and fruit set also related. The market prices, and especially the fall in prices as the season progresses, also appear to prevent growers from improving their yield, likely as the input prices and labour costs to keep picking, or to pick second grade fruit, is not balanced by the market prices.

Challenges have varied depending on the growing region. Growers in Gingin, Carnarvon and Kununurra usually face issues with sunburnt fruit; the Carnarvon region also often experiences strong winds. Queensland and NT growers have experienced flowering and fruit set issues due to warmer temperatures this growing season.

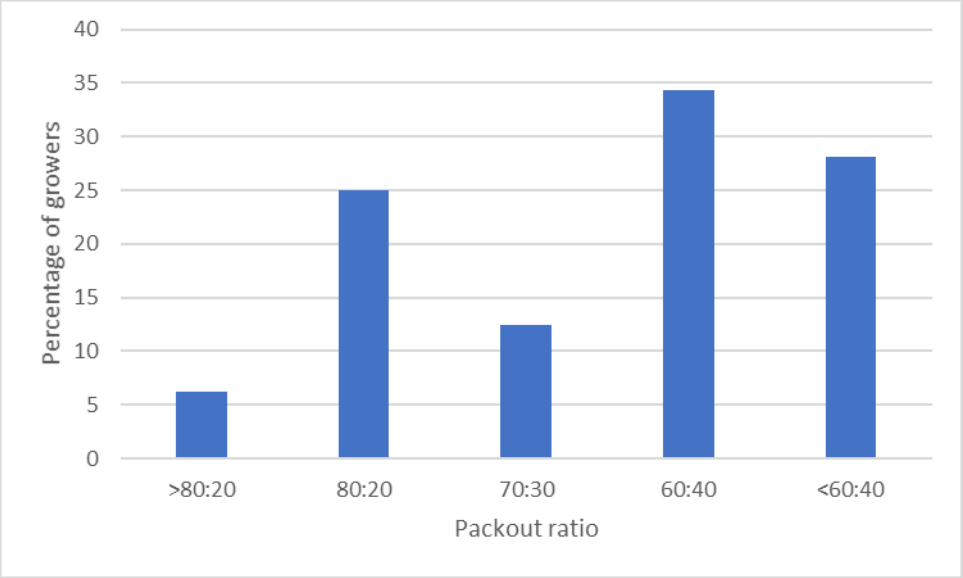
Below is selected direct feedback from growers:

Queensland	Rockhampton/Bundaberg	Issues at fruit set. Weather: heavy rainfall during early fruit growth period, irregular weather during flowering.
	Mareeba/Dimbulah & Bowen/Burdekin	Weather, price of inputs.
NT	Darwin/Katherine	Issues at flowering and fruit set, some varieties performing better than others, pests and diseases.
WA	Kununurra	Heat, sunburnt fruit, labour shortages.
	Carnarvon	Weather: sunburn, strong winds affecting fruit grading, wet winter causing bacterial spot issues, market prices as competing with Queensland fruit, labour shortages.
	Gingin	Weather: sunburn, cold spring leading to pollination issues, repetitive heatwaves at early development stages causing crop losses.

While we can't control the weather, resources to assist growers better understand how to manage sunburn, manipulate flowering and the impact of climate change, etc. would be helpful.

13. What is your average packout rate (Class 1/Class 2 ratio)?

As seen in the below graph, nearly half of growers stated their average packout rate was 60:40. 7 growers stated their ratio was 80:20 with only a handful of growers who had a higher Class 1 ratio than this. 9 growers stated their packout rate was lower than 60:40. According to the previous benchmarking report, the top 10 businesses have achieved ratios of 67:33. As the current industry majority is below this rate, further effort can be made to improve fruit quality and lift the Class 1 ratio. There were no distinct differences found between states.

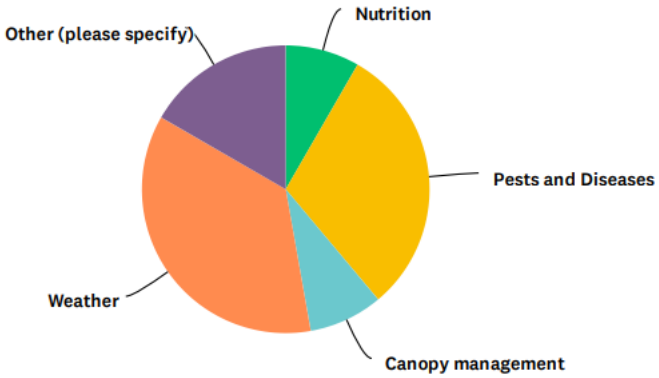


14. What are the current barriers preventing you from improving fruit quality?

Similar to question 12, the most common barrier to preventing growers from improving fruit quality was weather. This is followed closely by pests and diseases.

Many growers noted their concerns regarding the availability of registered chemicals to control the pests and diseases of concern. When asked to elaborate further, some growers stated their concern was regarding newly registered chemicals being expensive, and not providing the same coverage as old chemistry with rates sometimes being ambiguous.

Other issues included labour shortages and the lack of reliable and experienced workers, frequently mentioned by our respondents, which has been a challenge across all mango-growing regions of Australia, and especially in WA which had the strictest border restrictions due to COVID-19.



15. Any other notes/comments?

More attention to marketing and export was noted by many growers, particularly regarding the export of variety R2E2. Growers also noted pressure on the domestic market during the peak of the season and the drop in prices, with some requesting additional assistance in obtaining a regular and reasonable price for their product.

Q2 Please state your town and state:

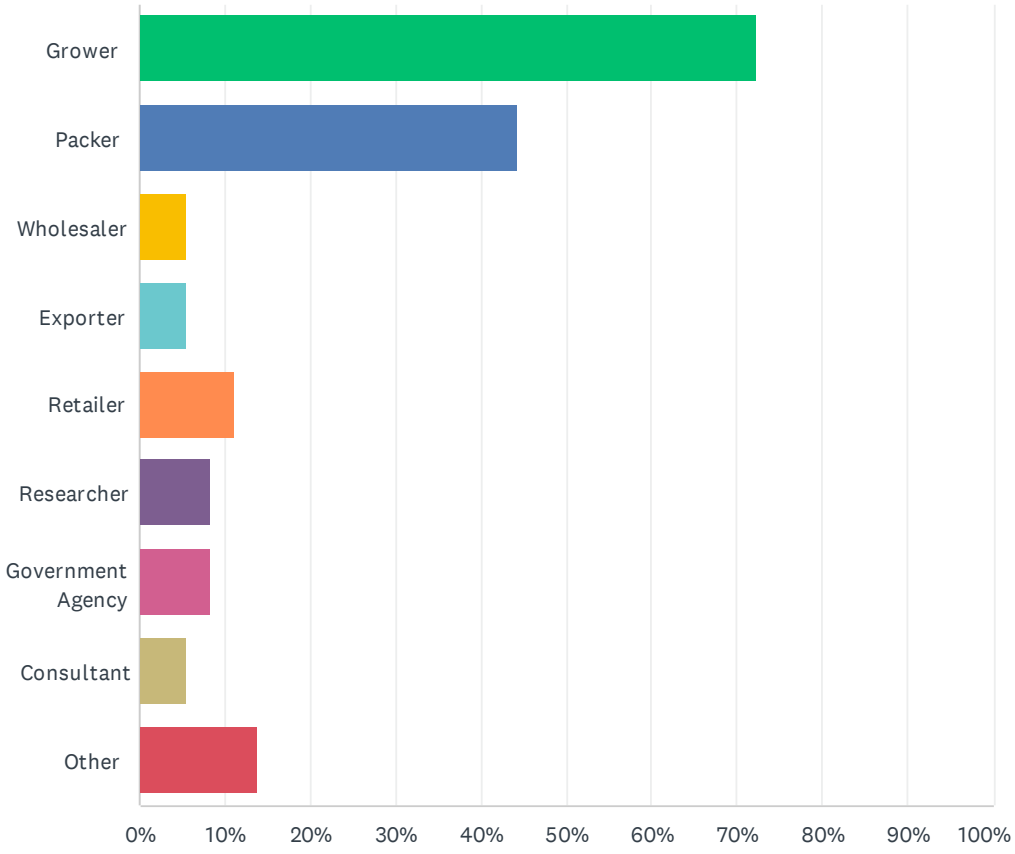
Answered: 36 Skipped: 1

#	RESPONSES	DATE
1	Darwin, Katherine, Mataranka NT	1/24/2022 6:01 PM
2	Mareeba, Qld	1/21/2022 2:36 PM
3	Gingin, WA	1/21/2022 2:29 PM
4	Bowen, Qld	1/21/2022 2:19 PM
5	Brandon, Qld	1/21/2022 2:00 PM
6	Rockhampton, Qld	1/21/2022 1:27 PM
7	KUNUNURRA	1/20/2022 7:58 PM
8	Perth WA	1/20/2022 6:54 PM
9	Katherine NT	1/20/2022 6:11 PM
10	Berry Springs NT	1/20/2022 1:27 PM
11	Thornton, New South Wales	1/20/2022 12:37 PM
12	Darwin NT	1/20/2022 12:16 PM
13	Dandaragan, Western Australia	1/19/2022 5:47 PM
14	Ayr Queensland	1/19/2022 3:27 PM
15	Giru Qld	1/19/2022 12:22 PM
16	Narellan Vale NSW	1/19/2022 7:54 AM
17	Childers, Qld	1/18/2022 7:43 PM
18	Auckland, New Zealand	1/18/2022 5:24 PM
19	Gingin WA	1/17/2022 1:43 PM
20	Katherine NT Burdekin & tablelands, Qld	1/12/2022 7:02 AM
21	Yelgun NSW	12/23/2021 3:54 PM
22	Lambells Lagoon NT	12/22/2021 1:02 PM
23	Mareeba, Qld	12/17/2021 4:06 PM
24	Brisbane Qld	12/15/2021 8:19 AM
25	Mutchilba Qld	12/8/2021 8:09 PM
26	NT humpty doo	12/6/2021 11:00 PM
27	Qld	12/6/2021 9:00 PM
28	Humpty Doo NT	12/6/2021 6:47 PM
29	Brisbane Queensland	12/6/2021 5:42 PM
30	DIMBULAH	12/6/2021 4:36 PM
31	Bowen, QLD	12/6/2021 4:01 PM
32	Dimbulah QLD	12/6/2021 3:49 PM
33	Tolga, Queensland	12/6/2021 1:47 PM

34	Sydney NSW	12/6/2021 1:44 PM
35	Melbourne	12/6/2021 1:15 PM
36	Mareeba, QLD	11/30/2021 3:42 PM

Q3 Please select the respondent category that applies to you from the following list (select all that apply):

Answered: 36 Skipped: 1



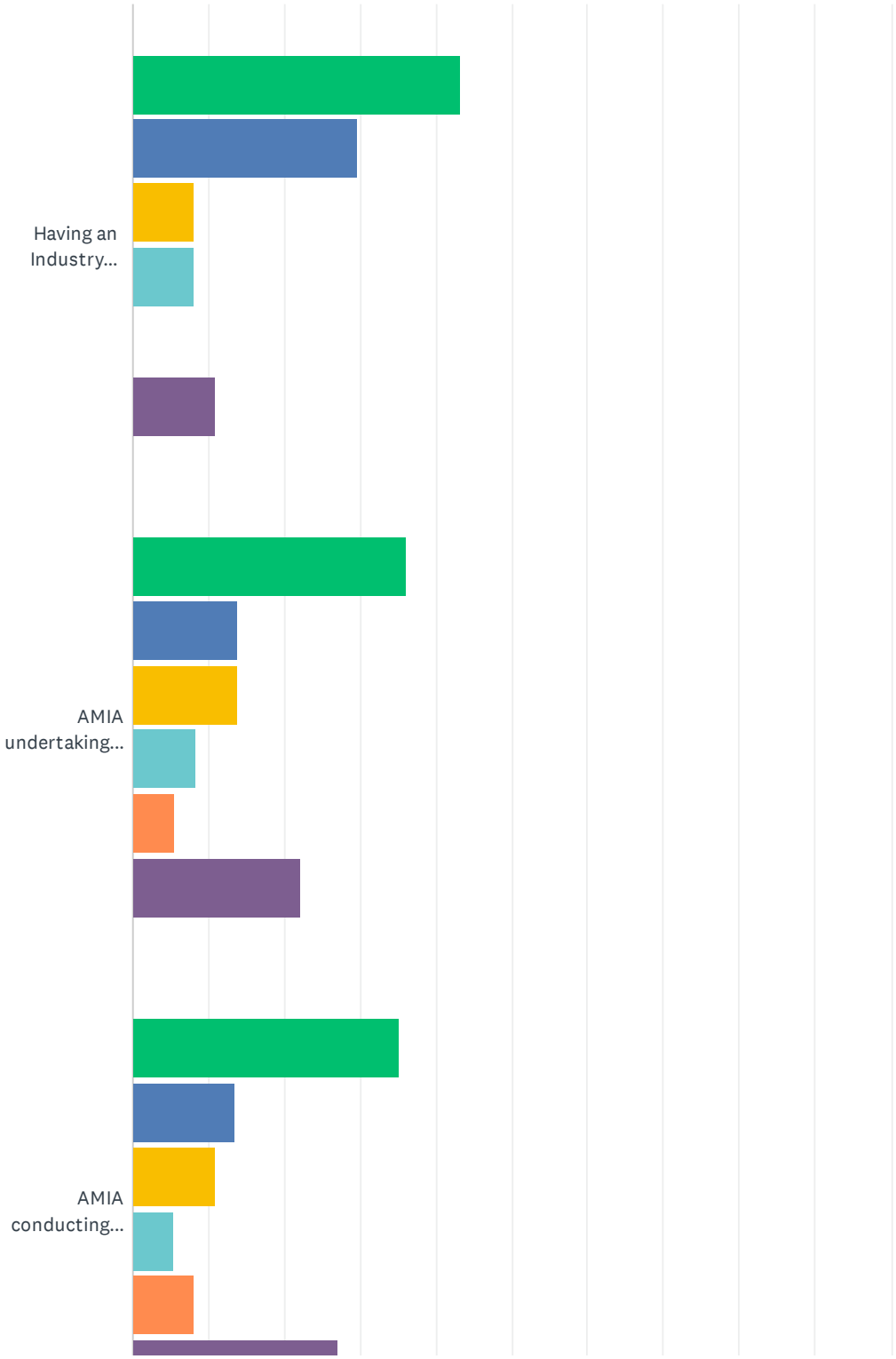
ANSWER CHOICES	RESPONSES	
Grower	72.22%	26
Packer	44.44%	16
Wholesaler	5.56%	2
Exporter	5.56%	2
Retailer	11.11%	4
Researcher	8.33%	3
Government Agency	8.33%	3
Consultant	5.56%	2
Other	13.89%	5
Total Respondents: 36		

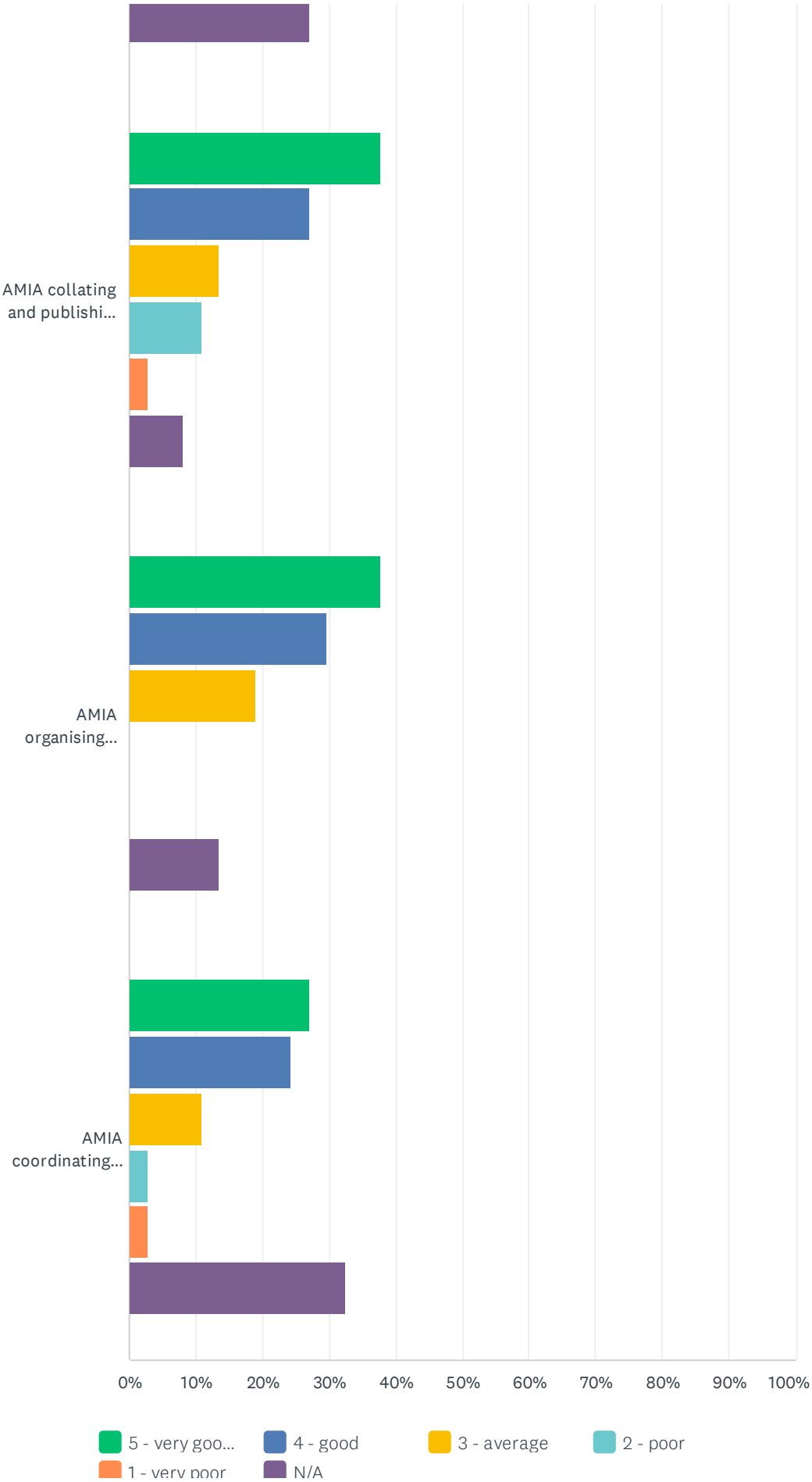
#	OTHER (PLEASE SPECIFY):	DATE

1	Board Member	1/20/2022 7:58 PM
2	Hort Innovation - investor, Regional Extension Manager	1/20/2022 6:54 PM
3	Writer/Reporter	1/20/2022 12:37 PM
4	Supermarket (Countdown)	1/18/2022 5:24 PM
5	Marketer	1/12/2022 7:02 AM
6	Industry Association (this is always left off)	12/6/2021 6:47 PM
7	Extension officer	11/30/2021 3:42 PM

Q9 Regarding the Best Practice Program, how you would rate the activities below based on the value they brought to your business on a scale from 5 (very good) to 1 (very poor) (select one option; select N/A if you don't use the relevant resource):

Answered: 37 Skipped: 0




AMIA collating and publishi...
AMIA organising...
AMIA coordinating...
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
5 - very goo...
4 - good
3 - average
2 - poor
1 - very poor
N/A

	5 - VERY GOOD	4 - GOOD	3 - AVERAGE	2 - POOR	1 - VERY POOR	N/A	TOTAL	WEIGHTED AVERAGE
Having an Industry Development Manager and two regionally based Industry Development Officers	43.24% 16	29.73% 11	8.11% 3	8.11% 3	0.00% 0	10.81% 4	37	4.21
AMIA undertaking field maturity testing using NIR technology (Felix machines) in the lead up to harvest	36.11% 13	13.89% 5	13.89% 5	8.33% 3	5.56% 2	22.22% 8	36	3.86
AMIA conducting calibration of Felix NIR machines	35.14% 13	13.51% 5	10.81% 4	5.41% 2	8.11% 3	27.03% 10	37	3.85
AMIA collating and publishing crop forecast and weekly crop flow reports	37.84% 14	27.03% 10	13.51% 5	10.81% 4	2.70% 1	8.11% 3	37	3.94
AMIA organising pre-season roadshows (COVID-dependent)	37.84% 14	29.73% 11	18.92% 7	0.00% 0	0.00% 0	13.51% 5	37	4.22
AMIA coordinating export registration for protocol markets	27.03% 10	24.32% 9	10.81% 4	2.70% 1	2.70% 1	32.43% 12	37	4.04

Q10 Please comment here if you would like to provide any further feedback on any aspect of the Best Practice Program, such as what we're doing well, or what could be improved (please detail what you are referring to if applicable) etc.:

Answered: 16 Skipped: 21

#	RESPONSES	DATE
1	The roadshows are the greatest tool, would prefer the attendance of Brett next time.	1/21/2022 2:36 PM
2	Review of the NIR % standards. Pre-season roadshows are only good if Brett is there in person for better feedback and conversation.	1/21/2022 2:19 PM
3	Interested in growers buying their own NIR guns and getting a good bulk deal. Calibration is important, but not Review of the crop forecast and crop flow reports - would like to talk with Brett. Are retailers looking at this to negotiate lower prices for growers? Go to retailers, tie crop forecasting in with sustainable farming? Growers need to know they will get at least $X per tray. Sustainable farming is very trendy right now - promotion (individual contracts, remove predatory purchasing, minimum tray prices). Qld do not get the same prices as the NT - greater pricing balance required. Post-season review every season.	1/21/2022 2:00 PM
4	Very happy with the contact provided by the IDO, no need for extra visits to the SEQ region.	1/21/2022 1:27 PM
5	Look forward to becoming more familiar with the mango industry activities in the West.	1/20/2022 6:54 PM
6	I would like to see a best practice booklet/manual published to be distributed to growers.	1/20/2022 1:27 PM
7	N/A	1/20/2022 12:37 PM
8	Just like what you have produced with putting the video of new pruning, high-density planting... can you do some for best Practice Program.	1/19/2022 5:47 PM
9	Please ignore these suggestions if they are outside of the AMIA scope. There appears to be some changes in regards to the following issues that could have a significant effect on the cost of mango production. GFS1 requirements for post harvest treatments in recirculating water systems. Piece rate employment requirements Labour availability with current visa changes	1/19/2022 12:22 PM
10	We still had so many suppliers send in mangoes with poor maturity. It's great that we are testing leading up to the season but if that is all we are doing "testing" and not holding to account I is hard to change it	1/19/2022 7:54 AM
11	It would be great to have more information on nutrition, especially in WA. The soil can vary a lot and having a targeted approach to nutrition would help individual growers to manage their orchards accordingly. Maybe a topic of interest for next roadshow/workshop	1/17/2022 1:43 PM
12	Needs to support and provide better value for growers who are already taking initiative in the basic areas. To some extent, oversupporting unmotivayed growers and doing their job for them.	1/12/2022 7:02 AM
13	More field days or farm visits to innovative farms, packhouses etc.	12/17/2021 4:06 PM
14	Tests need to be conducted on the NIR gun to show its degree of accuracy on mango maturity. To have confidence growers that growers using the gun as a indicator to harvest are harvesting at the correct timing, and not using the guns readings as a reasoning to harvest earlier.	12/8/2021 8:09 PM
15	Incidence of mango related biosecurity issues, predominantly Qld fruit fly issues in SA and TAS have been causing disruption in supply over recent years where fumigation does not seem to be effective. It would great to understand more from AMIA whether there are any initiatives to improve this issue going forward.	12/6/2021 5:42 PM
16	Everything can be improved the AMIA is doing nothing for the KP grower it is all for the	12/6/2021 4:36 PM

	Calypso & Honey Gold growers. The mango industry is in a very bad way, the industry needs to educate the consumer on the different varieties. This NIR technology has done nothing but reduce the quality of mangoes on the market.	

Outputs details

Table 1. Farm visits conducted over the 2021/22 season

Region	Farms (% of industry in	Varieties	Period	Visits
Kununurra, WA	9 ***85%***	KP, R2E2, Honey Gold, Other	1/05/2021-02/03/2022	12
Darwin, NT	16 ***80%***	KP, R2E2, Calypso, Honey Gold, Other, green eating varieties	1/05/2021-02/03/2022	37
Katherine, NT	11 ***95%***	KP, R2E2, Honey Gold, Calypso, Other	1/05/2021-02/03/2022	27
Bowen/Burdekin, QLD	20 ***95%***	KP, R2E2, Honey Gold, NMBP Varieties, Lady Grace and Lady	1/05/2021-02/03/2022	36
Mareeba/Dimbulah, QLD	21 ***89%***	KP, R2E2, Calypso, Honey Gold, Keitt, Brooks, Pearl, Palmer, NMBP	1/05/2021-02/03/2022	45
SEQ and NNSW	2 ***14%***	KP, R2E2, Calypso, Honey Gold, Keitt, Brooks, NMBP Varieties	1/05/2021-02/03/2022	4
Carnarvon, WA	0*	KP, R2E2, Honey Gold, Calypso, Kent, Valencia Pride, Heidi, Other	1/05/2021-02/03/2022	0
Gingin, WA	0*	KP, R2E2, Kent, NMBP Varieties, green eating varieties	1/05/2021-02/03/2022	0
8 regions	**79**		1/05/2021-	**161**

**While farm visits in WA were not possible during the past season due to COVID-19 border restrictions, and travel was limited to SEQ and Northern NSW, the IDOs have maintained regular phone contact with growers in these regions throughout the season.*

Table 2. Number of NIR readings per season and per region.

Region	2018/19	2019/20	2020/21	2021/22	Grand Total
Bowen/Burdekin	1,949	3,420	1,951	1,679	8,999
Carnarvon	2,675	604	224	1,028	4,531
Darwin	902	308	125	350	1,685
Gingin	365	480	0	76 *	921
Katherine	436	112	174	736	1,458
Mareeba/Dimbulah	2,795	3,275	3,673	2,801	12,544
South Qld	915	539	0	166	1,620
Kununurra	422	90	0	142	654
Grand Total	**10,459**	**8,828**	**6,147**	**6,978**	**32,412**

**NIR Testing is still current in the Gingin region*

Note: The number of NIR readings is generally lower in Darwin and Katherine due to a number of growers having their own NIR instruments. COVID-19 and border restrictions have also been additional obstacles in providing dry matter testing services, especially in Western Australia for the 2020/21 season. AMIA has coordinated local consultants to undertake dry matter testing for our growers where possible, using AMIA's NIR instrument and providing all necessary support when needed.

Table 3. Felix NIR Calibrations Summary – 2018-22

Date	Varieties/Fruit condition	Number of machines included	Conducted by
11/9/19	Calypso – Hard Green	5	NT IDO
16/9/19	Kensington Pride - Hard Green	15	NT IDO
	R2E2 – Hard Green		
1/11/19	Honey Gold – Hard Green	2	NT IDO
	Honey Gold – Ripe		NT IDO
12/11/19	NMBP 1201 – Hard Green	2	QLD IDO
	NMBP 1243 – Hard Green		
	NMBP 4069 – Hard Green		
	Honey Gold – Hard Green		
	R2E2 – Hard Green		
3/12/19	Calypso – Ripe	3	QLD IDO
	Kensington Pride – Ripe		
	NMBP 1201 – Hard Green		
	NMBP 1243 – Hard Green		
	NMBP 1243 – Ripe		
7/1/20	NMBP 1243 – Ripe	1	QLD IDO
9/1/20	NMBP 4069 – Hard Green	1	QLD IDO
5/2/20	Keitt - Ripe	1	QLD IDO
17/9/20	Calypso – Hard Green	5	NT IDO
23/9/20	Calypso - Ripe	6	NT IDO
23/9/20	R2E2 – Hard Green	1	QLD IDO
	Kensington Pride - Hard Green		
24/9/20	Kensington Pride - Hard Green	12	NT IDO
	R2E2 – Hard Green		
24/9/20	Kensington Pride – Ripe	5	Rudge Produce in Melbourne Market (coordinated by AMIA for retailer and market machines)
28/9/20	Kensington Pride – Ripe	8	NT IDO
	R2E2 - Ripe		
26/10/20	Honey Gold – Hard Green	2	NT IDO
5/11/20	Kensington Pride - Hard Green	1	QLD IDO
	R2E2 - Ripe		
10/11/20	R2E2 – Hard Green	1	QLD IDO
20/11/20	NMBP varieties (1201, 1243, 4069) – Hard Green	2	QLD IDO
27/11/20	NMBP varieties (1201, 1243) – Hard Green	2	QLD IDO
11/12/20	Honey Gold – Hard Green	2	QLD IDO
14/12/20	Keitt – Hard Green	2	QLD IDO
16/12/20	Calypso – Hard Green	2	QLD IDO
26/8/21	Kensington Pride - Hard Green	6	NT IDO
	R2E2 - Hard Green		
2/9/21	Calypso - Hard Green	4	NT IDO
8/9/21	Kensington Pride – Ripened	3	Rudge Produce in Melbourne Market (coordinated by AMIA for retailer and market machines)
	R2E2 - Ripened		
17/9/21	R2E2 - Hard Green	1	QLD IDO
1/10/21	Kensington Pride - Hard Green	1	QLD IDO
22/10/21	Honey Gold - Hard Green	2	NT IDO
1/11/21	Honey Gold – Hard Green	1	QLD IDO

Table 4. Mango preseason roadshows summary 2018-22

Growing regions	Year	Dates	Venues	Number of attendees
Kununurra, WA	2018	6/8/18	Parker Poynt Packhouse, Kununurra	36
Katherine, NT		8/8/18	Nutrano Produce Group packing shed, Katherine	45
Darwin, NT		9/8/18	Taminmin College, Humpty Doo	34
Bowen, QLD		17/9/18	Martos Mangoes, Bowen	30
Burdekin, QLD		18/9/18	Burdekin Theatre, Ayr	21
Mareeba/Dimbulah, QLD		20/9/18	John Nucifora Packhouse, Arriga	85
Rockhampton, QLD		15/11/18	Groves Tropical Fruits, Bungundarra	21
Bundaberg, QLD		16/11/18	Simpson Farms Packing Shed, Childers	12
Carnarvon, WA		11/12/18	Gascoyne Tropical Nursery, Carnarvon	
Gingin, WA		13/12/18	Market West Boardroom, Canning Vale	
Kununurra, WA	2019	5/8/19	Gulliver's Tavern, Kununurra	19
Katherine, NT		7/8/19	Godinymayin Yijard Rivers Arts and Culture Centre, Katherine	29
Darwin, NT		9/8/19	Darwin River Tavern, Darwin River	26
Bowen, QLD		19/8/19	DAF Bowen Research Facility, Bowen	27
Burdekin, QLD		21/8/19	Burdekin Theatre, Ayr	22
Mareeba/Dimbulah, QLD		22/8/19	FAVCO Goldpack Packing shed, Mutchilba	45
Rockhampton, QLD		31/10/19	Tim & Jenna Keogh's packing shed, Kabra	25
Bundaberg, QLD		1/11/19	Gin Gin & Dry, Gin Gin	31
Carnarvon, WA		10/12/19	Carnarvon Research Station, Carnarvon	33
Gingin, WA		12/12/19	Northern Valley Packers packing shed, Bindoon	17
Kununurra, WA	2020	These events were unable to occur due to COVID-19 restrictions on gatherings of more than 10 people. These were replaced by our webinar series which is detailed further below in this report.		
Darwin, NT		11/8/20	Darwin Export Hub, Darwin Airport	56
Katherine, NT		13/8/20	Nutrano Produce Group packing shed, Katherine	38
Bowen, QLD		These events were unable to occur due to COVID-19 restrictions on gatherings of more than 10 people. These were replaced by our webinar series which is detailed further below in this report.		
Burdekin, QLD				
Mareeba/Dimbulah, QLD				
Rockhampton, QLD		These roadshows will not occur this season due to growers not wishing to attend due to COVID-19 but the QLD IDO has replaced these events with farm visits in October and will visit again in December to conduct DM testing.		
Bundaberg, QLD				
Carnarvon, WA		15/10/20	Carnarvon Research Station	15
Gingin, WA		Individual farm visits were conducted due to the small number of commercial growers in the region.		5 (farm visits)
Kununurra, WA	2021	These events were unable to occur due to COVID-19 restrictions. These were replaced by our webinar series which is detailed further below in this report.		
Darwin, NT				
Katherine, NT				
Bowen, QLD		13/10/21	Bowen Research Facility	13
Burdekin, QLD		14/10/21	Burdekin Theatre, Ayr	7
Mareeba/Dimbulah, QLD		25/10/21	Mareeba Soccer Club	30
Rockhampton, QLD		23/11/21	Central Queensland University Rockhampton	14
Bundaberg &		24/11/21	Central Queensland University Bundaberg	11
Carnarvon, WA		8/12/21	Carnarvon Research Station, Carnarvon	27
Gingin, WA		18/1/22	Northern Valley Packers, Bindoon	10

Table 5. Australian mangoes field days and grower tours 2018/2022

Growing regions	Dates	Venues/Topic	Number of attendees
Darwin	17/5/19	Darwin processing plant	64
Mareeba	22/8/19	Manbulloo CRCNA high density trial and Diamond Star VHT plant	32
Bundaberg	1/11/19	Gin Gin & Dry processing plant	31
Mareeba	6/11/19	Walkamin Research Station, Intensive Horticulture Systems bus tour	22
Carnarvon	10/12/19	NMBP orchard walk	33
Brisbane	24/2/20	Mango Export Performance - end of season review	12
Darwin	23/03/21	Water Use Efficiency	39 (plus 21 exhibitors)
Katherine	25/03/21	Water Use Efficiency	48 (plus 19 exhibitors)
Bowen	27/07/21	Water Use Efficiency	26 (plus 14 exhibitors)
Mareeba	30/07/21	Water Use Efficiency	34 (plus 19 exhibitors)
Mareeba/Dimbulah	4/11/21	Mango Yield Mapping field walk at Manbulloo	15
Carnarvon	8/12/21	NMBP Varieties and high-density plantings	27

Table 6. Australian mangoes webinars 2018/2022

Growing regions	Dates	Topics	Number of attendees
NT	25/5/20	Covid-19 grower webinar	29 (89 YouTube views)
Qld	29/7/20	Covid-19 grower webinar	36 (76 YouTube views)
National webinar series	9/9/20	R&D Update	29 (68 YouTube views)
National webinar series	16/9/20	Multiscale monitoring tools for Australian tree crops project update	29 (115 YouTube views)
National webinar series	23/9/20	Marketing update	56 (94 YouTube views)
National webinar series	30/9/20	Chemical update	24 (93 YouTube views)
National webinar series	7/10/20	Export update	31 (113 YouTube views)
National	1/6/21	Export Information session	28 (93 YouTube views)
National webinar series	23/8/21	Labour Update	20 (48 YouTube views)
National webinar series	31/8/21	R&D Update	36 (120 YouTube views)
National webinar series	6/9/21	Hort Innovation Update	17 (78 YouTube views) *Video is unlisted but available upon request*

	Darwin	Katherine	Bowen	Mareeba
Date	23/03/2021	25/03/2021	27/07/2021	30/07/2021
Growers	39	48	26	34
Exhibitors	21	19	14	19
Survey respondents	23	28	14	17

1. QLD Water efficiency field day survey summary

Quick summary

- 34 attendees (plus 19 exhibitors) at the Mareeba field day and 26 attendees (plus 14 exhibitors) at the Bowen field day
- 31 total survey respondents
    - 14 surveys received from the Bowen field day
    - 17 surveys received from the Mareeba field day

Question 1 - Registration

- Over 90% of growers *agreed* or *strongly agreed* that the online registration process was easy to complete
- Only 8 respondents preferred to register at the door

Question 2 - How did you hear about the event?

- The largest cohort of growers heard of the event via email (14) and 7 from AMIA
- 3 attendees from Mareeba heard of the event from DAF
- 3 attendees heard of the event from a friend

Question 3 - How would you rate the event?

- The Bowen field day was rated as *very good* by 71.5% of attendees and *good* by the remaining 28.5%.
    - Average rating was 4.71 out of 5.
- The Mareeba field day was rated as *very good* by 35.5% of attendees, *good* by 58.8% and *average* by 5.8% (one grower).
    - Average rating was 4.29 out of 5.

Question 4 – Content

- “The topics covered were relevant to me and my business”
    - All attendees either *strongly agreed* or *agreed*
- The field trip enhanced the learning experience
    - All Bowen attendees and 94% of Mareeba attendees either *strongly agreed* or *agreed*
    - One Mareeba attendee *disagreed*
- I would be interested to learn more about irrigation efficiency in more detail
    - 93% of Bowen attendees 88% of Mareeba attendees either *strongly agreed* or *agreed*
    - 2 growers advised *neither* and one *disagreed*

- The exhibition displays were of interest to me
    - All Bowen attendees and 71% of Mareeba attendees either *strongly agreed* or *agreed*
    - 24% of Mareeba attendees said *neither* and one attendee *disagreed*
- I would attend a similar event in the future
    - 93% of Bowen attendees 94% of Mareeba attendees either *strongly agreed* or *agreed*
    - One grower from each field day advised *neither*

Question 5 – What topics would interest you to learn more about?

1. Irrigation pumps and systems - 20 attendees
2. Evapotranspiration - 16 attendees
3. Commercial irrigation design - 15 attendees
4. Other – 8 attendees
    - 2 growers mentioned fertigation systems
    - 2 growers mentioned moisture monitors
5. = Centre Pivot Lateral Move - 6 attendees
5. = Introduction to irrigation Agriculture – 6 Attendees
6. Meter installation and validation - 5 attendees

Question 6 – What was the best aspect of the day?

- 5 attendees in Bowen stated “all” was the best aspect
- 12 attendees across both field days stated the field trip was the best part
- One Bowen grower stated that they had a “great facilitator”
- Comments from the Mareeba field day included:
    - “Having people there that actually knew what they were talking about…”
    - “range of concepts covered”
    - “measuring sprinkler dispersion”
    - “It was all excellent”

Question 7 – Please rate your knowledge of irrigation (1 being very poor and 10 being excellent)

- In Bowen, before this event the average rating was 5.50. After the event this improved to 7.54 – 2.04 improvement.
- In Mareeba, before this event the average rating was 5.71. After the event this improved to 7.35 – 1.64 improvement.

Question 8 – Do you currently use soil moisture monitoring equipment?

- 50% of Bowen attendees and 62.5% of Mareeba attendees currently use equipment

Question 9 – If no, why not?

- In Mareeba, two growers stated the cost prohibited them from purchasing equipment
- One grower from each field day advised that lack of knowledge on which product to use prevented them from purchasing equipment
- Other comments include:
    - “one farm only”
    - “have had trouble with certain moisture probes”

Question 10 – What changes will you make after today?

- There were a large range of responses submitted
- Installing monitors and other irrigation equipment was mentioned by 5 attendees
- 2 attendees mentioned changing their irrigation scheduling

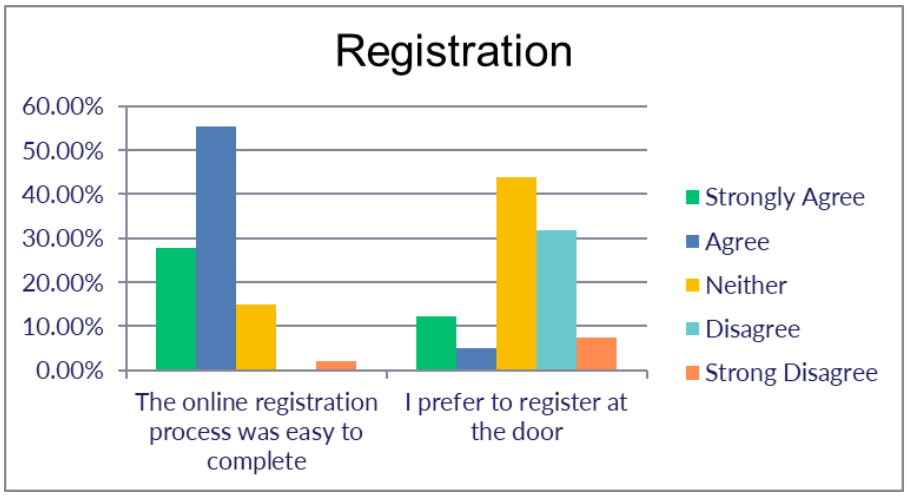
- Other comments include:
    - “check pressure + outputs across my system”
    - “irrigation uniformity across paddock, deeper irrigations”
    - “update current irrigation plan to include data capture enabling water distribution uniformity”

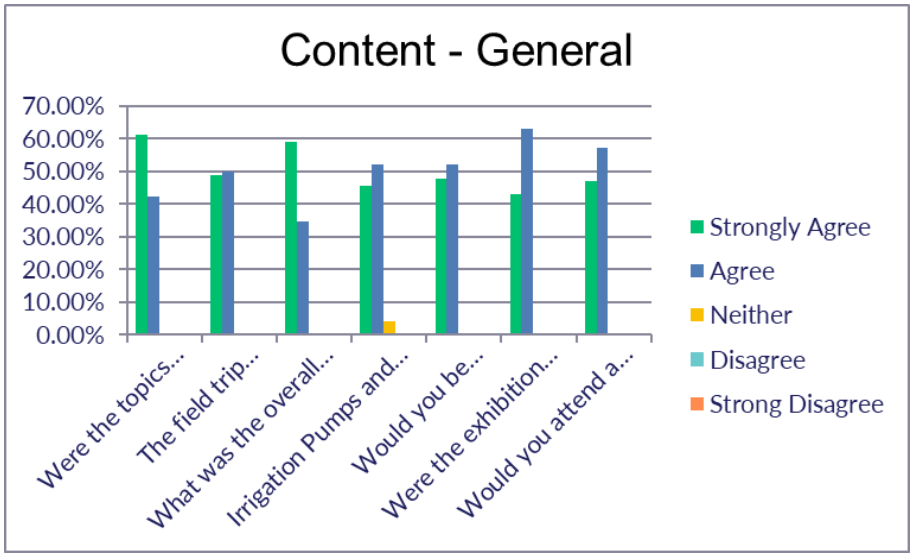
2. NT Water efficiency field day survey summary

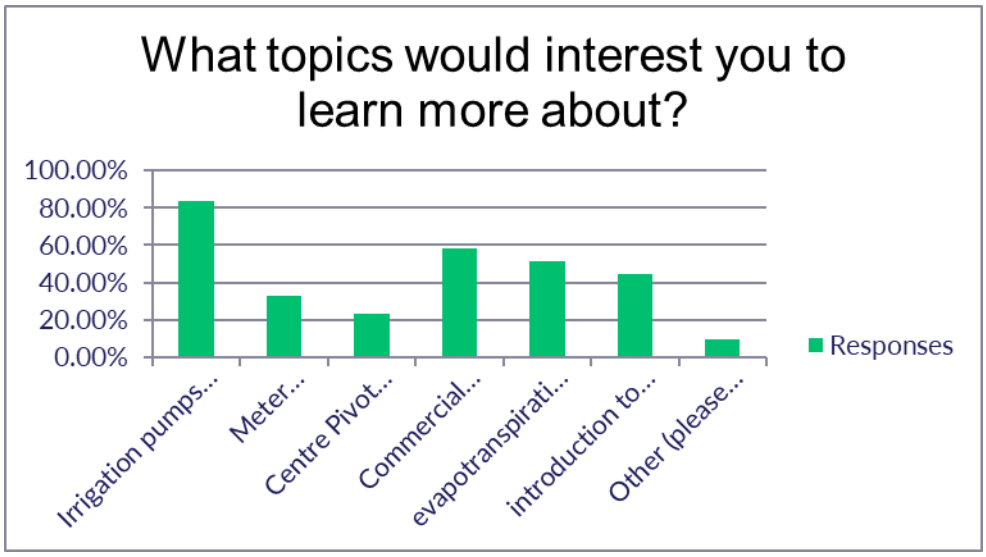
Quick summary

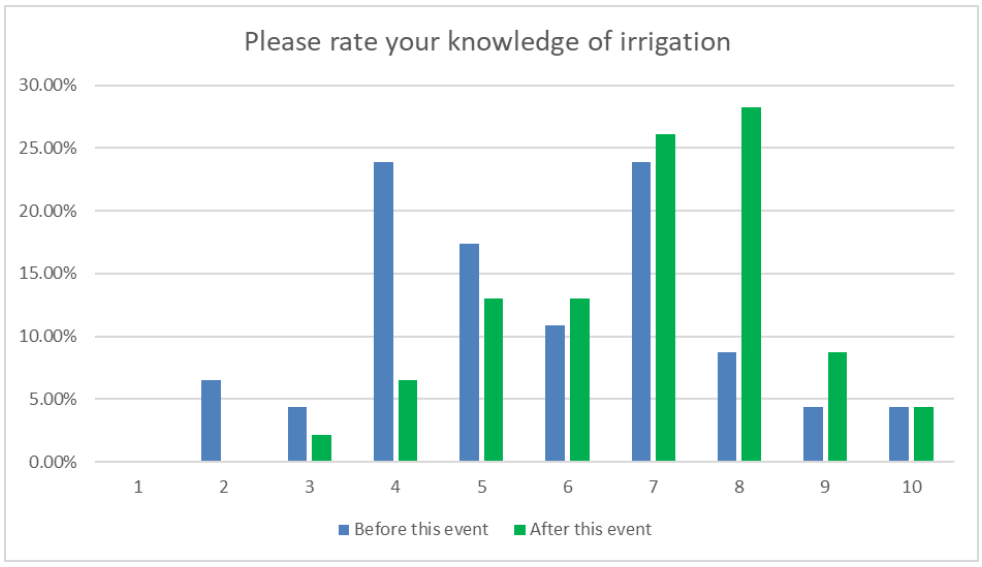
- 39 attendees (plus 21 exhibitors) at the Darwin field day and 48 attendees (plus 19 exhibitors) at the Katherine field day
- 51 total survey respondents
    - 23 surveys received from the Darwin field day
    - 28 surveys received from the Katherine field day

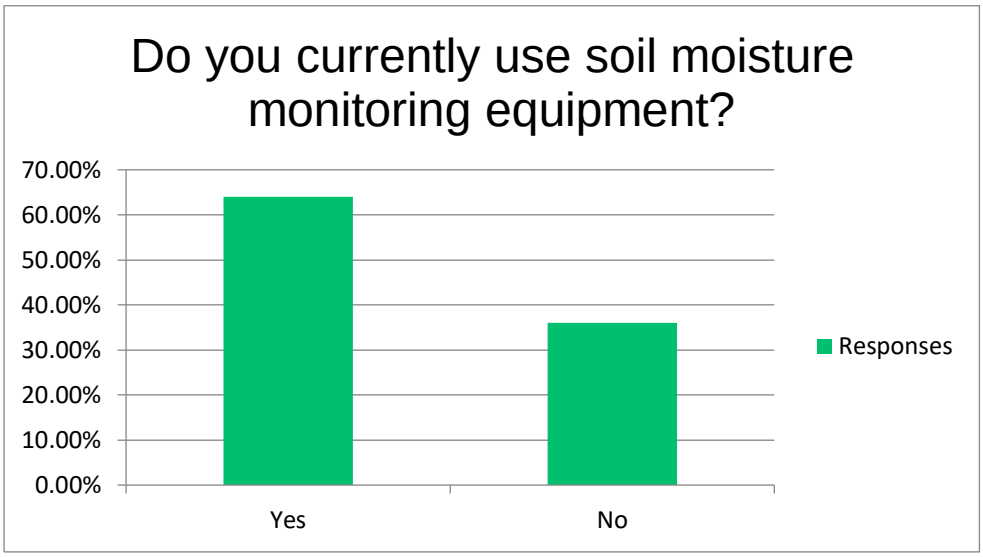
Survey results:



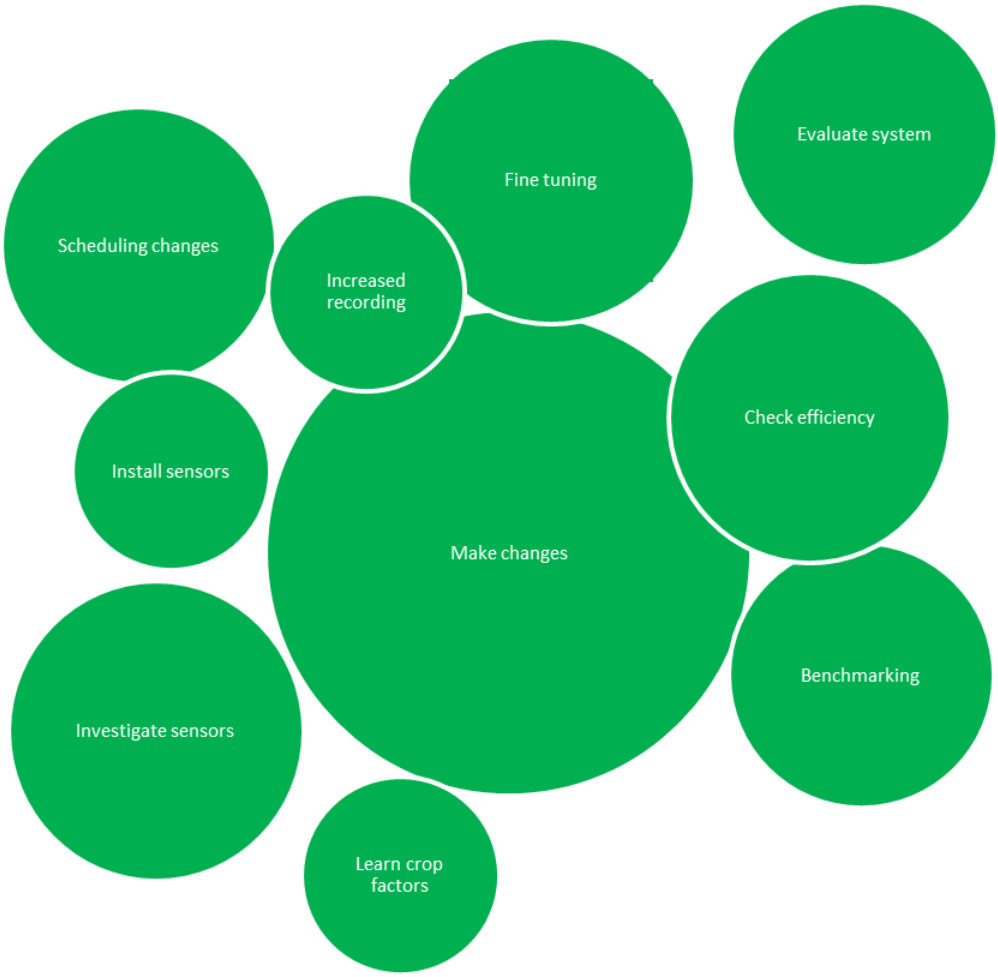



What topics would interest you to learn more about?
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
Irrigation pumps...
Meter...
Centre Pivot...
Commercial...
evapotranspirati...
introduction to...
Other (please...
Responses


Please rate your knowledge of irrigation
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1
2
3
4
5
6
7
8
9
10
Before this event
After this event


Do you currently use soil moisture monitoring equipment?
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Yes
No
Responses

What changes will you make after today?



Reflections from the organising group:

A post series meeting was held by related staff to identify what worked, and what improvements could be made for future events. The meeting prompted the following reflections:

- There was a clear change in intent and knowledge as a result of the workshop.
- The Cultural centre in Katherine was an excellent location.
- Growers were not put off by the fee, it may have ensured that they turned up.
- Growers were definitely attracted by the trade show, some did not attend the event but simply came to see the trade show.
- The participation rate was high, having IA involved allowed us to make it a very technical workshop and gave added incentive to growers.

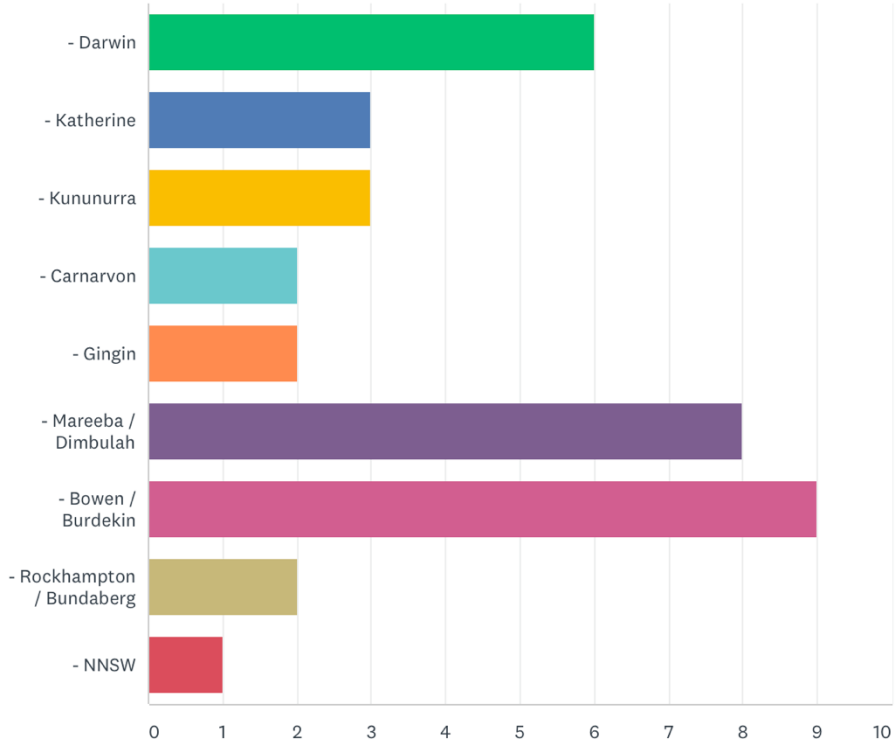
MG 17000 – BPR Survey Results

The purpose of this survey was to define the baseline practices for orchard management, harvesting and temperature management throughout the supply chain. It also aimed to understanding growers' learning preferences, so that the BPR team can prepare project resources which are tailored to their needs and which will be accessible through the Australian Mangoes website. A sample of 36 mango growers were surveyed between September 2019 and April 2020 by the two Australian Mangoes Industry Development Officers. The surveys were conducted either face-to face or by phone.
The survey results will assist the BPR team in identifying; the most appropriate communication and extensions methods, prioritising sub-topics for the development of resources and workshop/webinar content, and to provide a benchmark of current production practices. The following report provides a summary of the data collected and some recommendations.

I. Demographics

1. Location

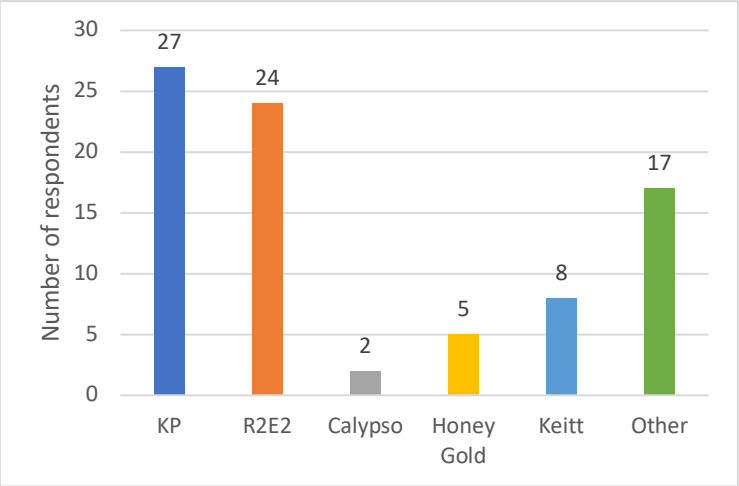
Which region is your property located in?



2. Variety

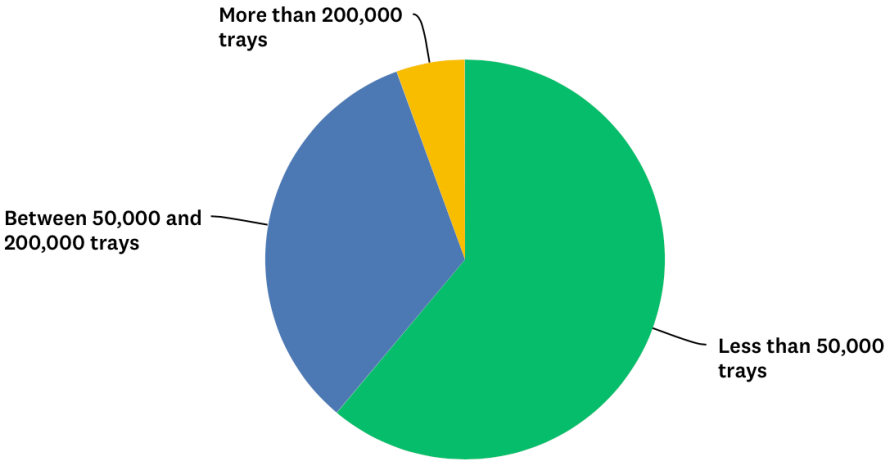
What variety/varieties do you grow?

Please note that the majority of respondents had more than one variety. "Other" includes Kent, Brooks, NMBP varieties, Lady Grace, Lady Jane, Keow Savoy, Nam Doc Mai and other green eating mangoes. A good cross section of the industry is represented here.



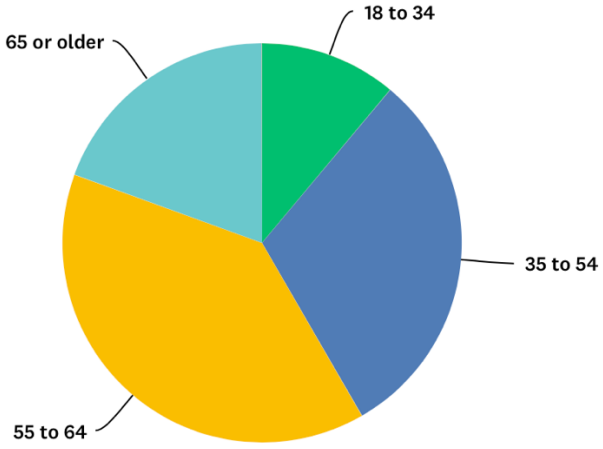
3. Scale

What is the average number of trays your orchard (7kg eq) produces per year?



4. Age

Which of the following age groups do you fall within?



5. Gender

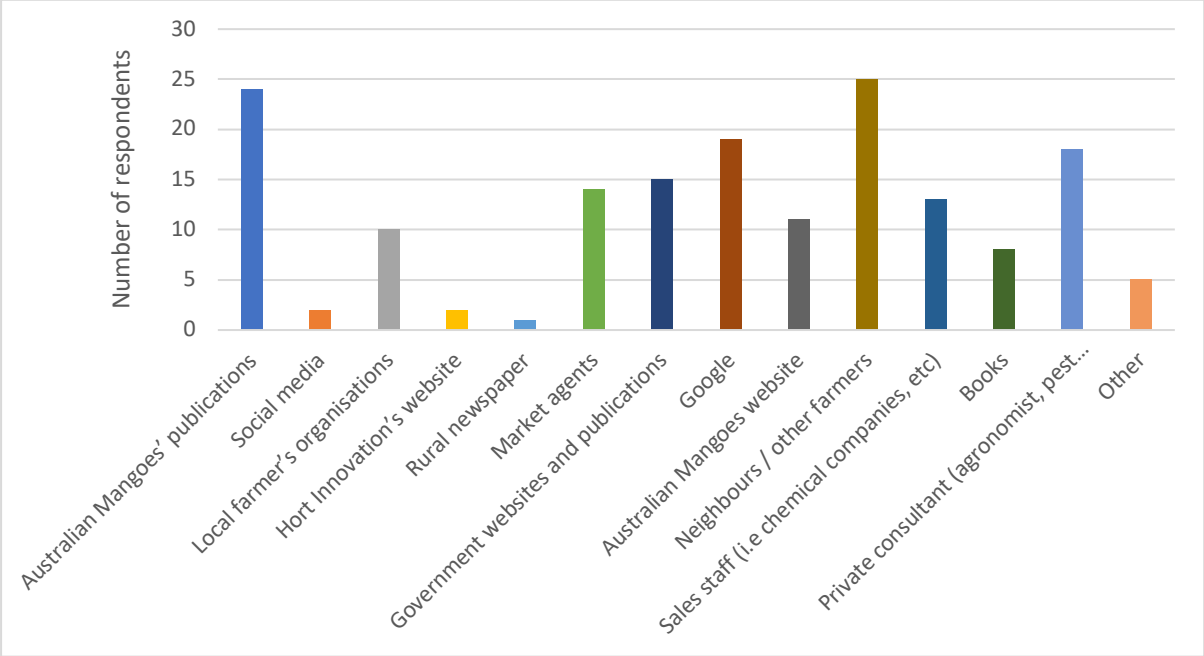
Silent question

Only two women were surveyed out of 36 respondents.

II. Learning preferences

1. Where do you seek / find out information relating to the mango industry?

Tick all that apply



These results highlight the need to have a centralised resource located on the Australian Mangoes website with regular updates provided through Australian Mangoes' publications. The figure also shows the important role that other growers and private consultants have in providing advice to industry. The BPR team could consider involving "champions" to promote the key messages.

2. How often do you visit the Australian Mangoes website? Is the information you are looking for easy to find?

Almost 90% of respondents indicated that they visit the Australian Mangoes website. The frequency of visits increased during the season.

Of those who visit the website, 37% of respondents always find the information they're after, 49% sometimes find what they're after and 14% respondents indicated that they can't find the information they're looking for.

These results highlight the need to update the Australian Mangoes website to ensure the information is easily accessible.

3. What is/are your preferred method(s) to develop your understanding and skills?

Tick all that apply

ANSWER CHOICES	RESPONSES	
- Attending field days	30	83%
- Talking to family/friends/neighbours	20	56%
- Getting involved in an on-farm research project	18	50%
- Attending a one-off information session	16	44%
- Obtaining advice/help from a professional	16	44%
- Undertaking own or group research	13	36%
- Belonging to a special interest group or network	8	22%
- Attending a formal education or training program	6	17%
- Enrolling in an online course	6	17%
- None of the above	0	0%

The BPR team will ensure that field days are conducted throughout the life of the project and that these include presentations from trusted growers. This indicates that most growers like practical based learning such as observing others' on-farm practices or seeing technology/ideas in action.

4. Have you used the Mango information kit from 1999 which was prepared and handed out by the Queensland DPI? If so, which aspects of this resource were most useful?

66% of respondents were aware of and had used this resource. Most respondents who were not aware of this resource were located outside of QLD where this resource was developed. This highlights the importance of having a national resource which can be regionally tailored where required.

Out of the 24 respondents who were aware of the resource, one didn't find it useful and one didn't respond. The other 22 responses were positive and used to generate the word cloud below and identify the most useful topics of this resource.

The more frequently the word was used, the larger it is displayed. As the word cloud shows, growers thought that it was a useful resource when starting and setting up an orchard. The pests and diseases section along with what chemicals to use to control them was the most frequently mentioned topic.

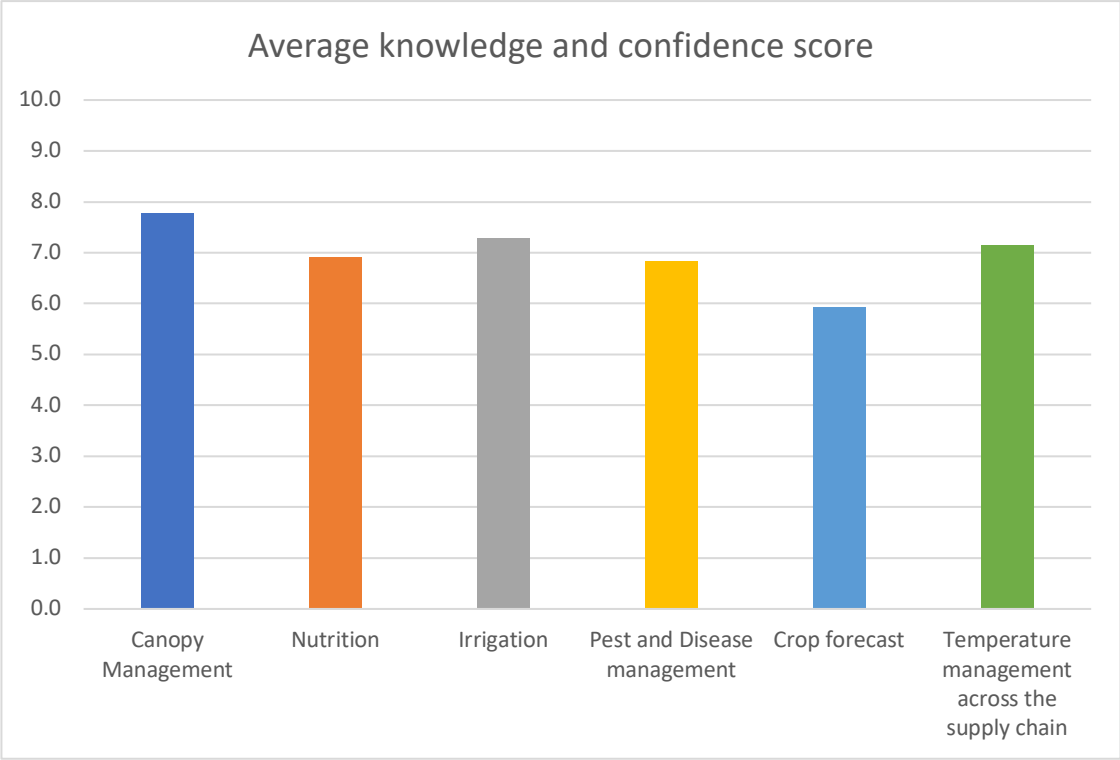
5. Which of the following schemes/accreditations do you currently participate in?

Schemes/Accreditations	**% Respondents**
Freshcare	94%
HARPS	61%
Export to protocol markets	28%
Interstate Certification Assurance (CTM01/ICA19)	19%

III. Production practices

1. Overview

Respondents were asked to rate their knowledge and confidence on a range of topics from 1 to 10 (with 1 being very poor and 10 being excellent). The figure below shows that growers rated themselves the lowest on crop forecast (5.9) and the highest on canopy management (7.8). These results will assist the BPR team in prioritising the development of resources and workshop content. For example, it would seem that growers would appreciate guidance on predicting their crop forecast.



2. Canopy management

a) Score

The respondents' average knowledge score for canopy management was 7.8 ranging from 5 to 10 (with 1 being very poor and 10 being excellent).

b) Annual pruning regime

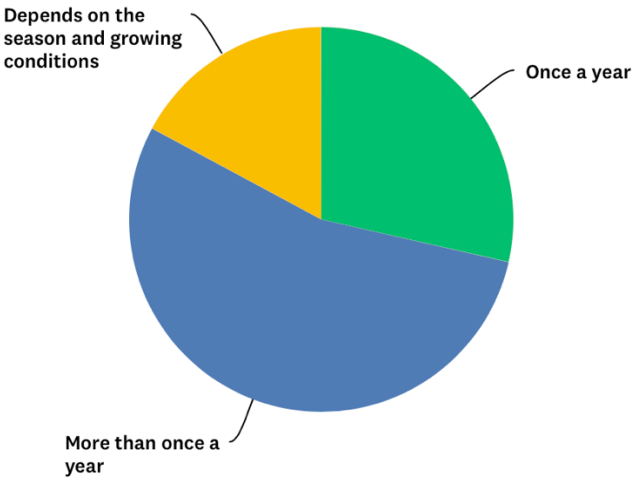
83% of respondents mechanically prune directly after harvest and hand prune (internally and remove dead wood) either at the same time of after the first flush.
Only one respondent mechanically prunes every second or third year to reduce impact on crop yield.
Six respondents indicated that they only hand prune, one due to the fact that the trees are still too young to be mechanically pruned.

It is also important to note some regional particularities. For example, in Northern NSW where one grower's trees only crop every second year, they are mechanically and hand pruned heavily on the year they won't crop and only hand pruned the year they will bear a crop.
In Kununurra where it is very hot and harsh and where the air is dry, growth rates are low and branches/fruit are highly susceptible to sunburn. Large canopies are maintained to cope with the severe conditions, particularly over the summer/wet season.
Gingin has cold winds and mild summers with heat waves so there is limited growth/flush on trees compared to other growing regions.
Carnarvon presents similarities to both Kununurra and Gingin.

c) Timing

More than 50% of respondents prune more than twice a year with some even pruning four times a year if required. The main reasons why growers are not pruning more than once a year are in order of importance:

- Don't think it would provide benefits/improvements (46%)
- Not applicable to my growing region/climate (39%)
- Scale (small business) (31%)
- Cost (23%)



3. Nutrition

a) Score

The respondents' average knowledge score for nutrition was 6.9 ranging from 4 to 9 (with 1 being very poor and 10 being excellent).

b) Property soil types

All respondents were aware of their property soil types but only 56% of them were managing them differently. The main reasons why growers didn't manage the different zones differently were:

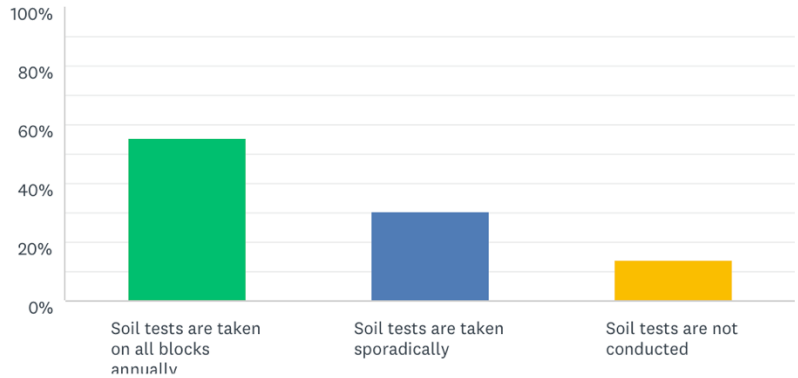
- Not needed as very slight differences
- Small farm
- Time, cost
- Only rely on leaf tissue analysis

c) Soil testing

56% (n=20) of respondents conduct soil testing on all blocks at least once a year. The main reasons why growers are taking soil samples only sporadically (30%, n=11) or not at all (14%, n=5) are in order of importance:

- Rely on leaf test and/or tree health (9/16)
- Not needed every year (3/16)

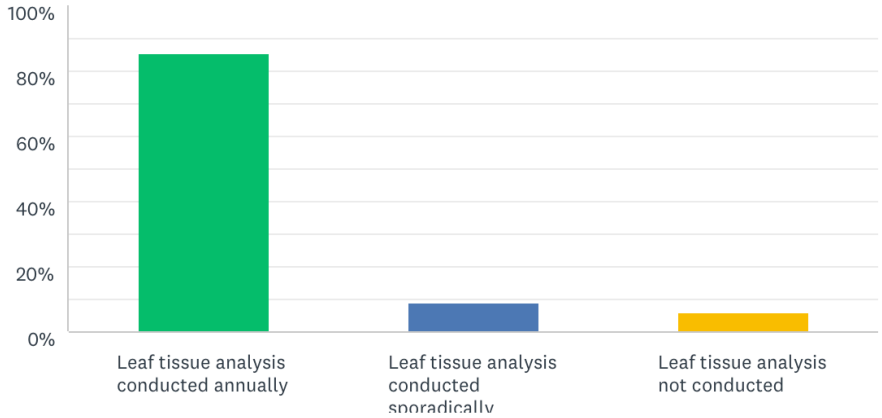
- Time and cost (3/16)
- Not on every block (1/16)



d) Leaf tissue analysis

84% of respondents conduct leaf tissue analysis every year. The main reasons why growers didn't conduct leaf tissue analysis every year were:

- Only every second year (6/8)
- Prefer to rely on visual tree health (2/8)



e) How do you apply nutrients?

Most respondents use fertigation (86%), solid (89%) and foliar (72%). Their choice of methods depends on the type of nutrient they're applying and the timing. For example, foliar was used by most growers but only once or twice a year for trace elements.

4. Irrigation

a) Score

The respondents' average knowledge score for irrigation was 7.3 ranging from 4 to 10 (with 1 being very poor and 10 being excellent).

b) Soil moisture monitoring equipment

Automated scheduling based on soil moisture monitoring equipment at different depths	6%
Scheduling based on soil moisture monitoring equipment	56%
No soil moisture equipment is used to develop an irrigation schedule	39%

Most growers who did not use automated scheduling or monitoring equipment commented on the cost of the infrastructure.

c) Irrigation systems

What type of irrigation system are you using?

89% of respondents use under-tree sprinklers and 11% use drip irrigation.

5. Pests and diseases

a) Score

The respondents' average knowledge score for pests and diseases was 6.8 ranging from 4 to 9 (with 1 being very poor and 10 being excellent).

b) How do you monitor for pests and disease?

Seven respondents (19%) didn't specifically monitor for pests and diseases with five respondents checking for pests and diseases while conducting other tasks in the orchards and two respondents not checking at all and applying pesticides on a calendar basis. The rest either did it themselves or contracted a pest scout (81%). It is important to note that growers who are registered for export to protocol markets (28% of respondents) are required to perform weekly or fortnightly crop surveillance.

The main reasons why some respondents didn't monitor specifically for pests and diseases were in order of importance:

- Scale (small business) (43%)
- Don't think it would provide benefits/improvements (43%)
- Cost (28.5%)
- Time (28.5%)

c) How do you manage the use of agrochemicals throughout the year to counter the development of resistance?

94.5% of respondents rotate chemicals and follow product label instructions. Only two respondents didn't rotate chemicals because they only apply very minimal amount of pesticides or the environmental conditions were not conducive to fungal diseases.

d) How often do you calibrate your spraying equipment?

Given that spraying equipment calibration is a requirement under Freshcare and that 94% of respondents are Freshcare accredited, most growers surveyed calibrate their spraying equipment once a year (61%) or more than once a year (31%).

6. Crop forecasting

a) Score

The respondents' average confidence score for crop forecasting is 5.9 ranging from 2 to 9 (with 1 being very poor and 10 being excellent). The lowest scoring of all topics.

b) How do you currently estimate volume of production?

Full transect fruit count survey is conducted and orchard variability is accounted for	50%	18
Informal observations are conducted	39%	14
Estimations based on gut feel and past experience	11%	4

c) What methods do you use to determine your decision to pick?

89% of respondents use a wide range of methods to assess fruit maturity including internal flesh colour, shape, NIR dry matter percentage and comply with industry specifications. The remaining 11% use only one method to decide when to pick. These results might be skewed given that the data was collected by the IDOs from growers who they have an existing relationship with and therefore who are more likely to get their fruit tested for NIR dry matter percentage or have their own NIR machine.

d) Forecast data shared with industry

92% of respondents share their forecast data with industry with 72% providing an update regularly throughout the season. These results might be skewed given that the data was collected by the IDOs from growers who they have an existing relationship with and therefore who are more likely to be involved in industry crop forecast. However, Australian Mangoes receive forecast data that accounts for about 90% of mango volumes in Australia.

7. Temperature management across the supply chain

a) Score

The respondents' average confidence score for temperature management across the supply chain is 7.1 ranging from 3 to 10 (with 1 being very poor and 10 being excellent).

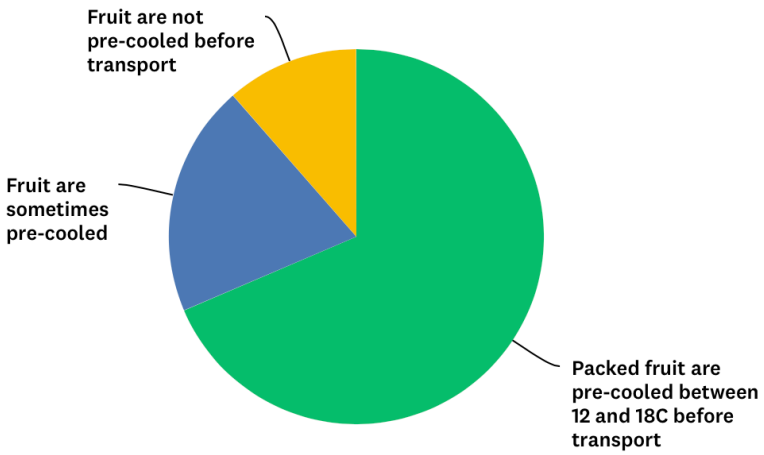
b) In field handling

92% of respondents protect their harvested fruit from the sun (cover bins, place bins in shade) and transport them back to the shed rapidly.

c) Post-harvest handling

The majority of growers (69%) pre-cool their fruit before transport. The main reasons why some don't do it every time (20%) or don't do it at all (11%) are:

- Cost (56%)
- Scale (small business) (44%)
- Don't think it would provide benefits/improvements (44%)
- Time (11%)
- Not applicable to my growing region/climate (11%)

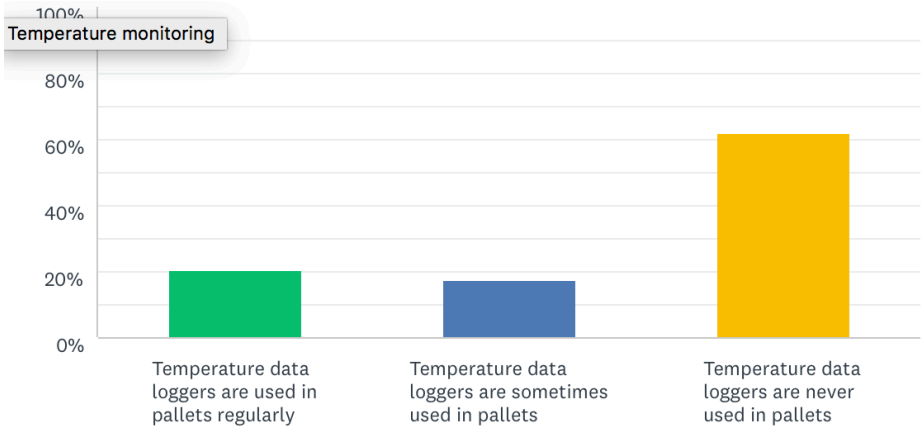


d) Temperature data loggers

60% of respondents have never used data loggers. The main reasons why growers didn't use data loggers regularly were:

- Other (47%)
- Because they don't think it would provide benefits (35%)
- Time (12%)
- Cost and scale (both at 6%)

Some of the responses under "Other" included the proximity to market and the fact that open trays helped solve temperature issues across the supply chain.



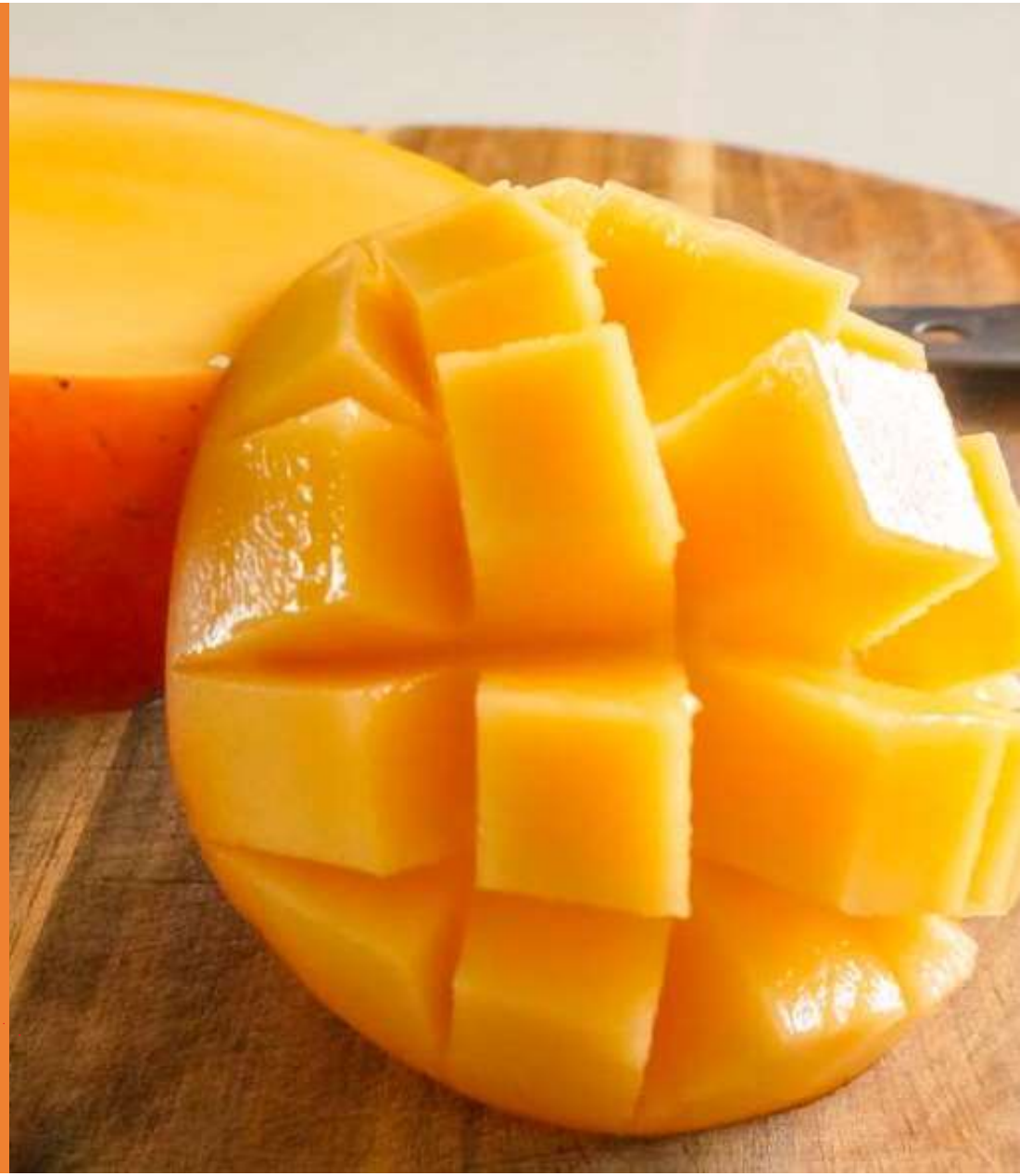
Australian Mango Industry Association

2019/20 and 2020/21 Seasonal Report

Internal document only, contains customer confidential information

escavox

QUALITY PRODUCE HAS A VOICE!



Contents

Background

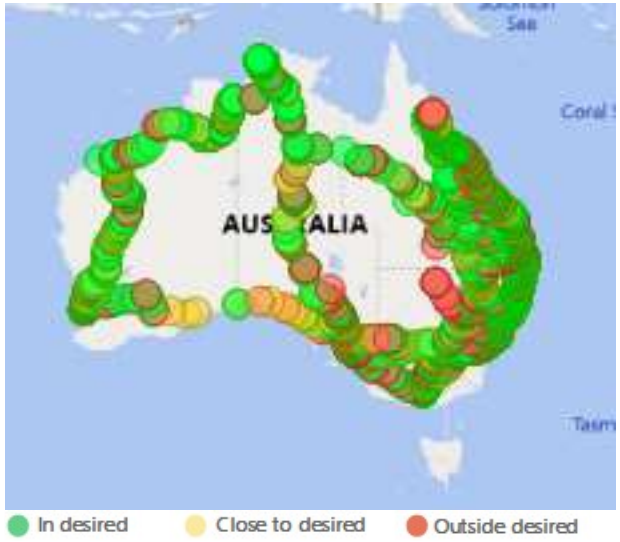
- 2019/20 and 2020/21 seasons were tracked
- Over both seasons a total of:
  - 30 participating growers
  - 182 completed domestic tracks
- Tracks assessed against industry recommended temperature ranges for three key legs of the supply chain
  - At packhouse: minimum 12˚C *
  - Packhouse to ripener (via transport): 12˚C-18˚C
  - At ripener (storage and ripening process): 12˚C-22˚C

**Note: In measuring performance of the supply chain, a maximum of 40˚C is used as the upper limit for temperature in the packhouse leg of the supply chain. This recognises the practical limitations of the supply chain in that fruit is unavoidably exposed to ambient conditions at different times in the packhouse.*

Participating growers in each region

Region	2019/20 season	2020/21 season
Darwin	2	5
Katherine	2	1
Kununurra	2	2
Bowen/Burdekin	7	5
Mareeba/Dimbulah	8	3
Central Queensland	0	2
Total growers	**21**	**18**

Right. *Temperature heat map of all tracks over the 2019/20 and 2020/21 seasons*



Overall Recommendations

- **Take the time to ensure fruit is pre-cooled before shipping**
  - *43% of tracks did not leave the packhouse in ideal temperature range*
  - *Precooling fruit has a knock on effect for the entire cold chain*
  - *Precooled fruit has 87% cold chain compliance for the entire journey, v's only 56% for non pre-cooled fruit*
- **Use your seasonal cold chain data in conversations with your freight providers to discuss overall cold chain compliance, not just when you have an issue**
- **Investigate correlation of reject/sales/feedback data with cold chain outcomes to fully link and understand the commercial impact of cold chain compliance**
- **Add information to show if fruit is intentionally ripened in transit**
  - *Analysis assumes product is moved and stored according to best practice temperatures. Therefore, any fruit that is intentionally ripened in transit may skew results*

Future Project considerations

- **Trackers that went all the way to stores showed that produce travelled at very low temperatures (an average of 4.6°C)**
  - Conduct a study of full end to end cold chain compliance through to store
  - Tracking this can help understand if this is a systemic issue that could impact quality of the fruit and subsequent customer experience

- **Supply chains appeared to improve over the two seasons tracked**
  - Is this from improving cold chains or other factors?
  - Potential other factors include, weather conditions between the two seasons, amount of fruit available, a greater understanding of the supply chain

Cold chain issues

Types of track issues identified

- **Precool success** is defined as ‘tracks that leave the packhouse between 12°C and 18°C’
    - **Too Cold** is if the track drops below 12°C during any part of the transit journey
- **Warm Load** is if the track is above the upper temperature limit during any part of the journey.
    - **Precool Failure** is if the track leaves the packhouse above 18˚C or below 12°C.

Overview of cold chain issues for both seasons

- **57% of tracks were Precooled successfully.**
- Tracks that are **pre-cooled successfully have the highest cold chain compliance** for the entire journey at 87% VOP.
- **43% of tracks had Precool Failure.**
- Tracks with **Pre-cool failure average only 56% cold chain compliance (VOP)** for the rest of the journey
- **Precool failure was most prevalent in December** for both seasons
- **10% of tracks are Too Cold.**
- **Tracks with Warm Loads experience on average 63% cold chain compliance (VOP).** Tracks that are precooled successfully are less likely to experience warm loads

2019/20 – 2020/21 Seasonal Overview

- Cold chain compliance **improved overall between the two seasons** (77 vs 102 tracks), with **less temperature issues**

- States ranked by VOP*
  1. WA (85%)**
  2. QLD (77%)
  3. NT (67%)***

  **VOP is 'Voice of Product', a measure of time spent in ideal temperature ranges for each stage of the supply chain*
  **fewest tracks
  ***biggest improvement between seasons

- Overall proportion of **Bad** VOP scoring tracks **decreased by 40%** in the 2020/21 season

- Average dwell times have increased, although includes new routes taken by growers.
  - e.g. some growers from NT sent mangoes to Perth via Adelaide

2019/20 vs 2020/21 seasons

- VOP scores **improved** from **Poor** to **Fair**
  (time in temperature 67% 2019/20 v's 78% 2020/21)
- Average temperature improved - **decreased by 1.4ºC** in the 2020/21 season
- Heat maps show **less 'red'** ie reduced temperature issues in 2020/21
- **11% decrease** in the number of tracks out of temp for more than 2hrs
  (2019/20 76%, 2020/21 65%)

VOP is 'Voice of Product', a measure of time in ideal temperature ranges for each stage of the supply chain

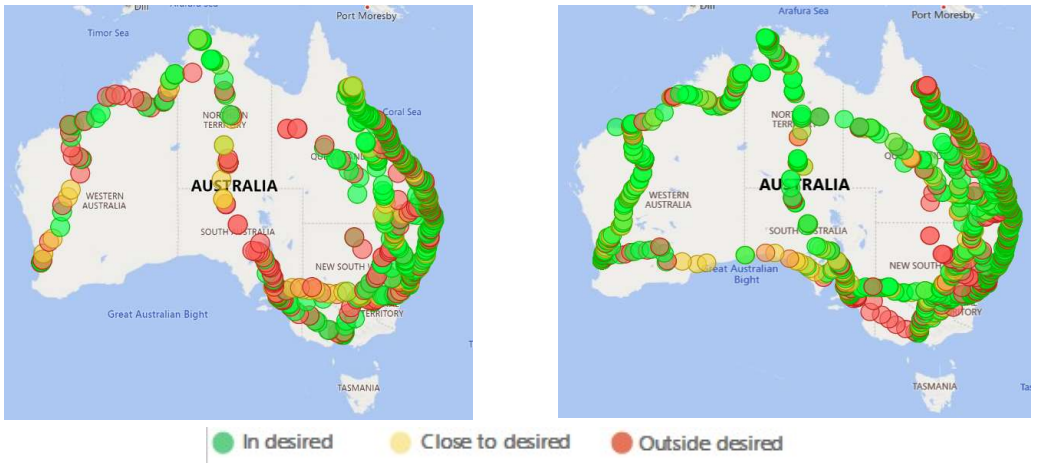
All States	VOP	Average Temp C	Average Dwell Time days	Average Time out of Temp (hrs)	# Tracks
Overall	75%	17.8	8.8	34.1	182
2019/20	67%	18.9	3.7	29.8	78
2020/21	78%	17.5	9.8	37.4 *	104

Above. *Overall voice of product (VOP) scores increased year on year*

* This season had one pack house that was an outlier in terms of time spent out of temperature. When this packhouse was removed from the data, the average time spent out of temperature decreased to an average of **22.7** hours out of temperature for the 2020/21 season.

VOP Scores
- Perfect 100%
- Excellent 90-99%
- Good 80-89%
- Fair 70-79%
- Poor 60-69%
- Bad < 60%

Below. *Heat maps of the 2019/20 season (left) and 2020/21 season (right)*



2019/20 vs 2020/21 - VOP

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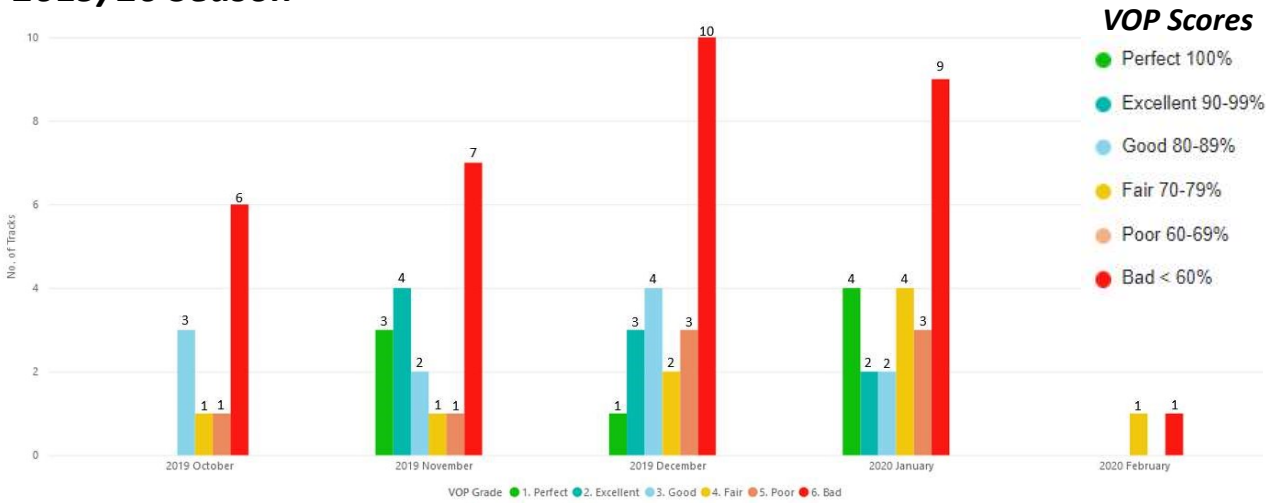
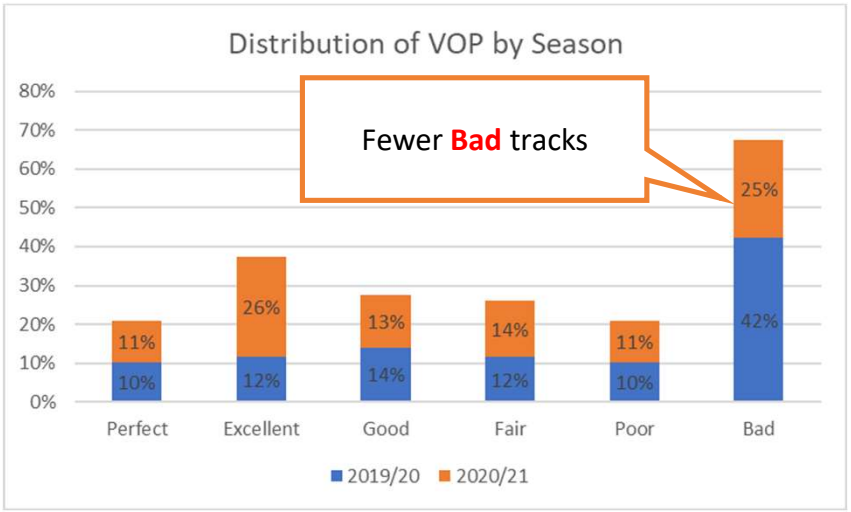
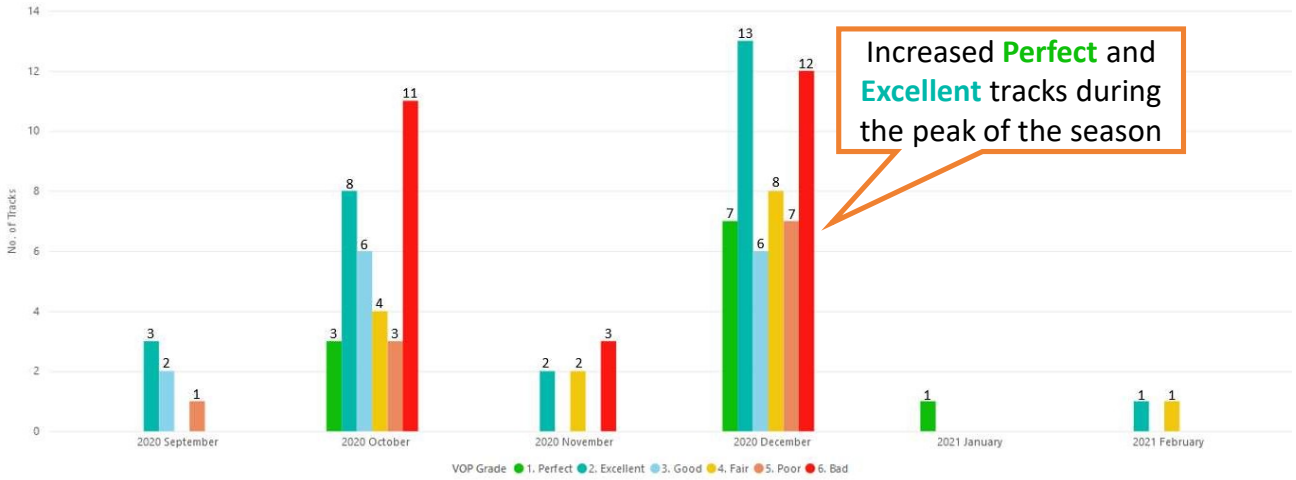
2019/20 Season





2020/21 Season



- 2020/21 season increase in **Perfect**, **Excellent**, **Fair** and **Poor** **tracks**
- Overall proportion of **Bad** tracks **decreased by 40%**
- Overall proportion of **Excellent** tracks **more than doubled, increasing by 116%**

VOP is 'Voice of Product', a measure of time in ideal temperature ranges for each stage of the supply chain

2019/20 vs 2020/21 – Track Issues Defined

- **Precool success** is defined as 'tracks that leaves the packhouse above 12°C'
- **Too Cold** is if the track drops below 12°C during any part of the transit journey (Pack to DC)
- **Warm Load** is if the track is too warm during any part of the journey (Pack to DC).
  E.g. temps are constantly too high (above 18˚C for transit or 22˚C at ripen) *or a warming load with gradually increasing temps.*
- **Precool Failure** is if the track leaves the packhouse above 18˚C or below 12°C.
  E.g. the produce may be too chilled before leaving pack or not chilled enough.

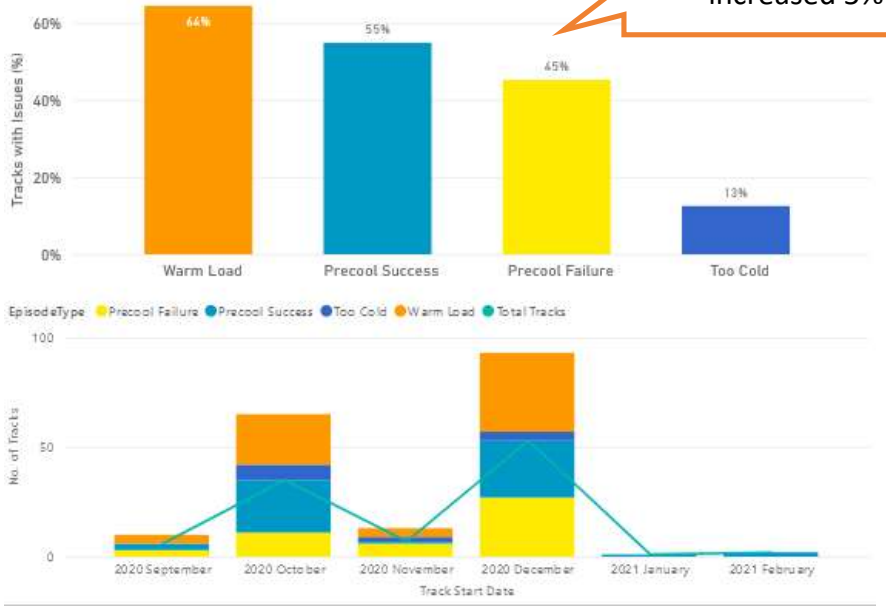
2019/20 vs 2020/21 - Pack Leg Issues

2019/20 Season

Data is filtered to show issues in Pack leg

2020/21 Season

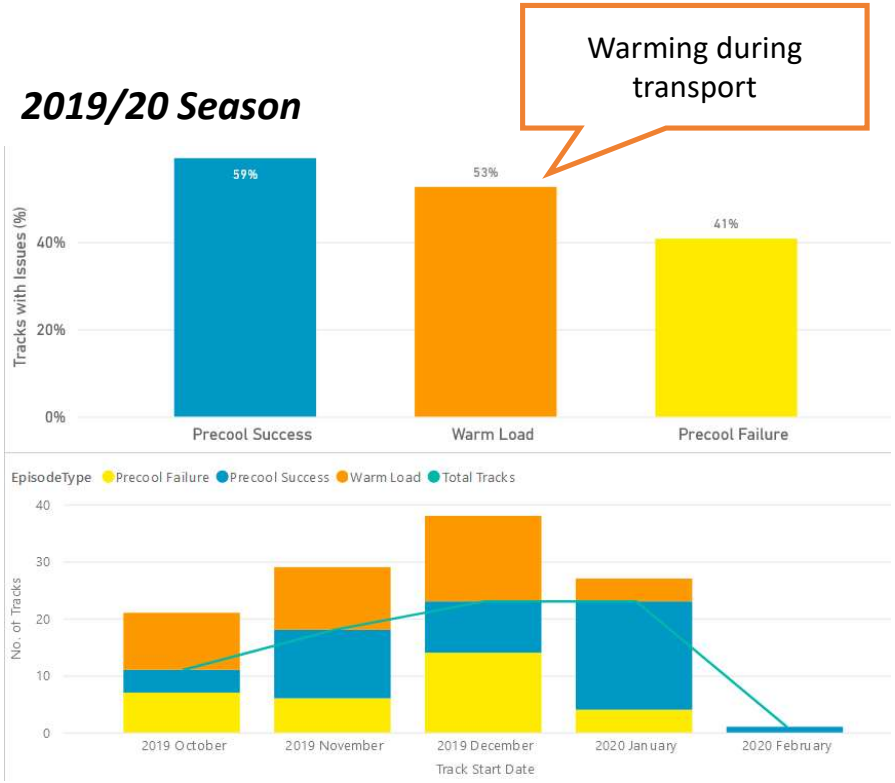
Precool failures increased 5%



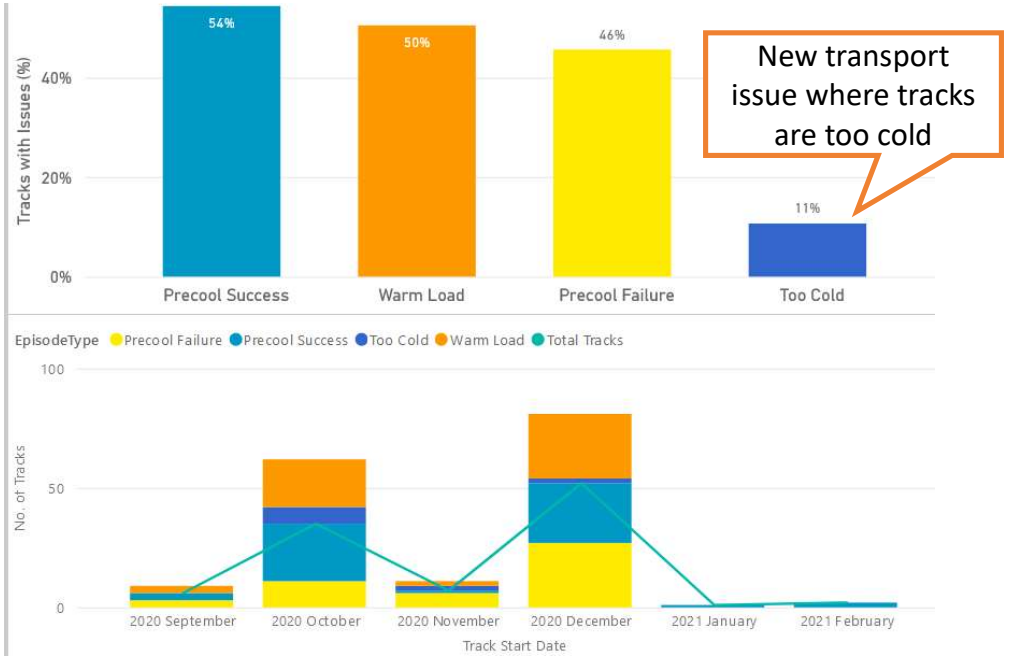
- Precool success is defined as ‘tracks that leaves the packhouse between 12-18C’
- Pre-cooling is critical to help preserve quality and prolong shelf life. Even if fruit is to be partially ripened in-transit, it should be cooled to 18°C, prior to dispatch
- Most pre-cooling failures were in December

2019/20 vs 2020/21 – Pack to Ripen Leg Issues

2019/20 Season

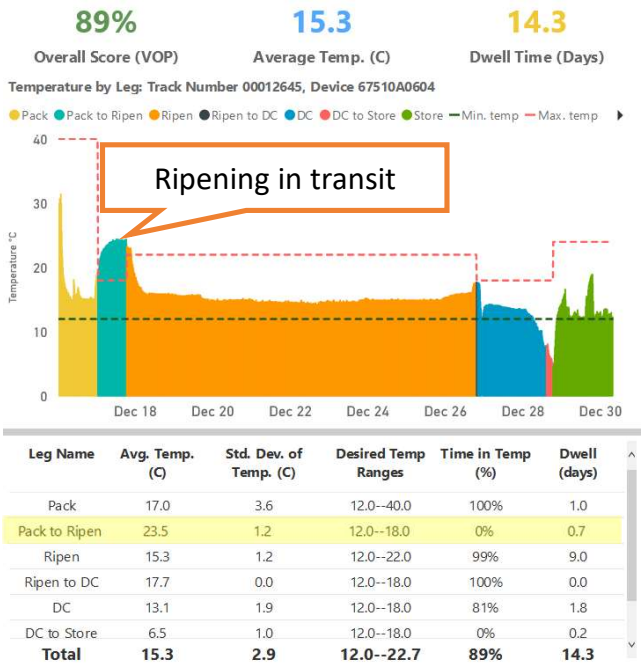


2020/21 Season

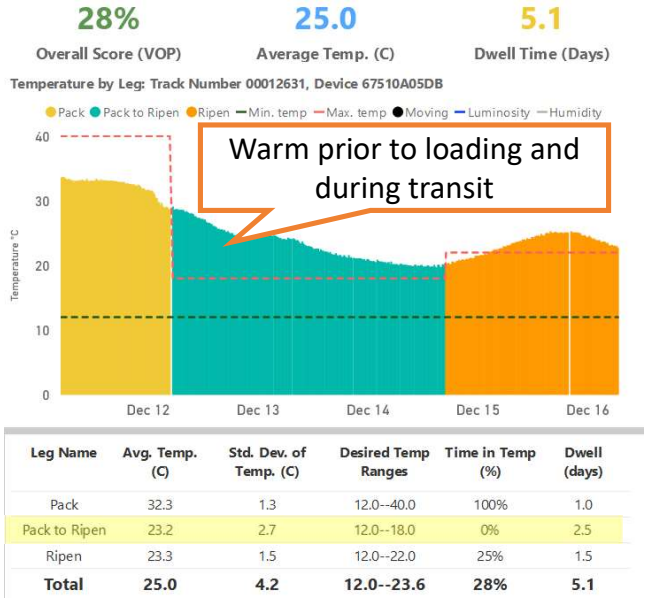


- Slight decrease in percentage of warm loads between seasons
- Warm loads occurred more frequently in Dec, possibly due to warmer weather conditions
- Warming loads may also be loads ripened in transit
- Cold/too cold loads were only seen in 2020/21 season

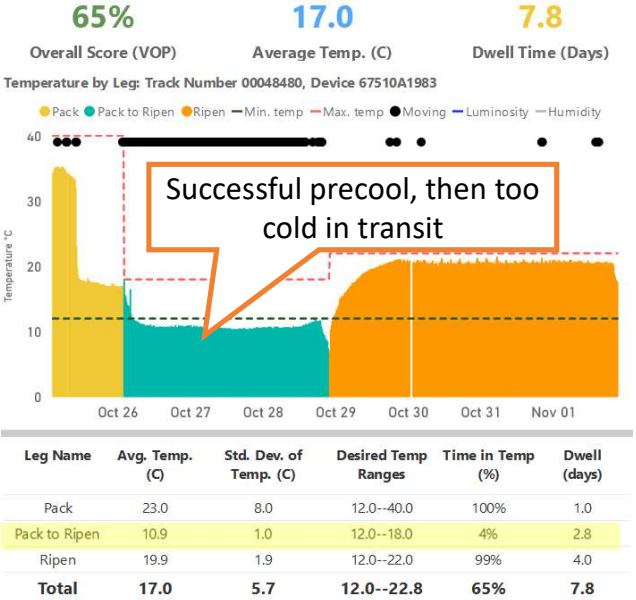
Pack to Ripen Leg Issues Examples



Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	17.0	3.6	12.0--40.0	100%	1.0
Pack to Ripen	23.5	1.2	12.0--18.0	0%	0.7
Ripen	15.3	1.2	12.0--22.0	99%	9.0
Ripen to DC	17.7	0.0	12.0--18.0	100%	0.0
DC	13.1	1.9	12.0--18.0	81%	1.8
DC to Store	6.5	1.0	12.0--18.0	0%	0.2
Total	**15.3**	**2.9**	**12.0--22.7**	**89%**	**14.3**



Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	32.3	1.3	12.0--40.0	100%	1.0
Pack to Ripen	23.2	2.7	12.0--18.0	0%	2.5
Ripen	23.3	1.5	12.0--22.0	25%	1.5
Total	**25.0**	**4.2**	**12.0--23.6**	**28%**	**5.1**



Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	23.0	8.0	12.0--40.0	100%	1.0
Pack to Ripen	10.9	1.0	12.0--18.0	4%	2.8
Ripen	19.9	1.9	12.0--22.0	99%	4.0
Total	**17.0**	**5.7**	**12.0--22.8**	**65%**	**7.8**

Potential intentional warm load

- *Temp averaged 23.5°C in transit*
- *Ripen temperatures only 15.3°C (more storage range)*

Potential warm load issue

- *Temp averaged 23.2°C in transit*
- *Pack temperatures warm, produce not pre-cooled before loading successfully*
- *Ripen temperatures in ripening range 23.3°C*

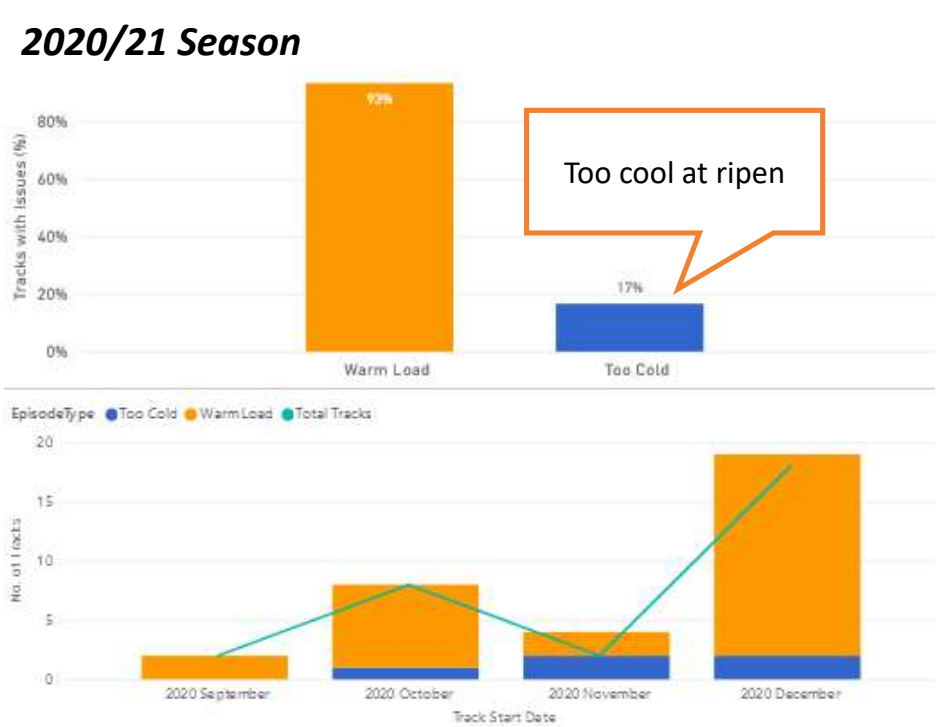
Too cold load issue

- *Temp averaged 10.9°C in transit*
- *Pack temperatures successfully pre-cooled*
- *Negative impact on end consumer product*

2019/20 vs 2020/21 – Ripening Leg Issues

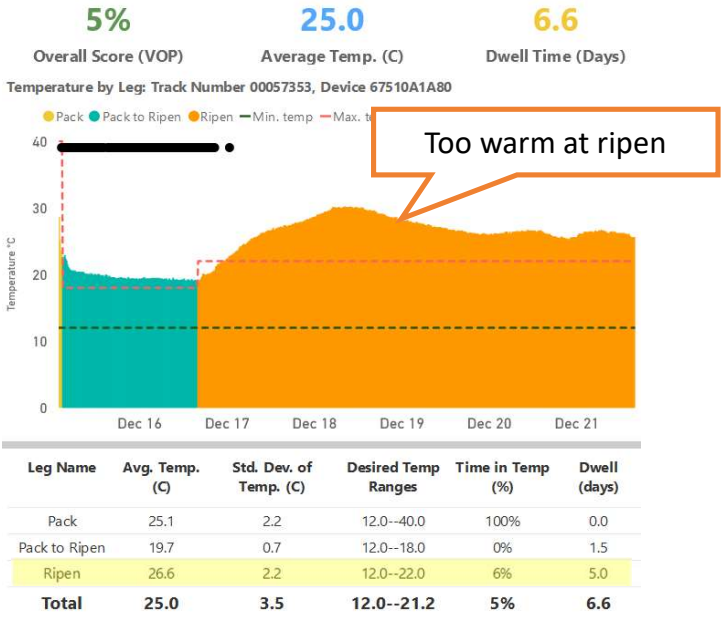
2019/20 Season

2020/21 Season

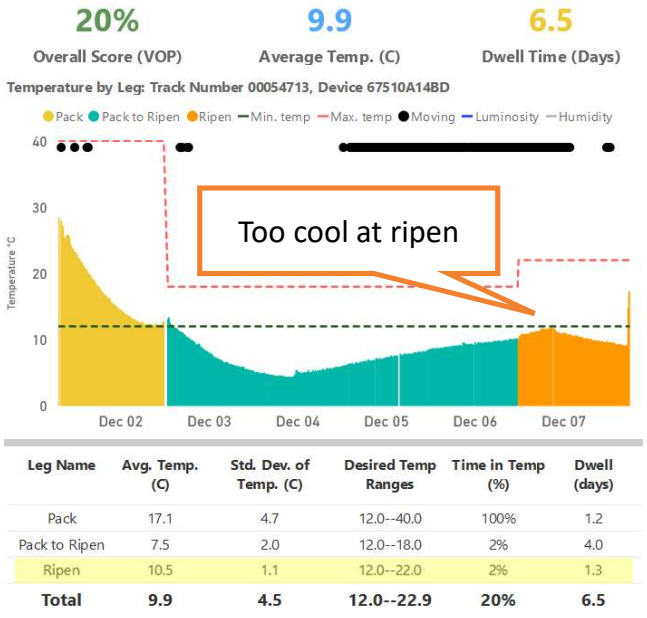


- 2019/20 season, 100% of tracks experienced issues in temperature at the ripening facilities
  - The 2020/21 season had less tracks that experienced too cold issues at ripening (8%)
    - Some tracks in 2020/21 season were both a warm load and too cool

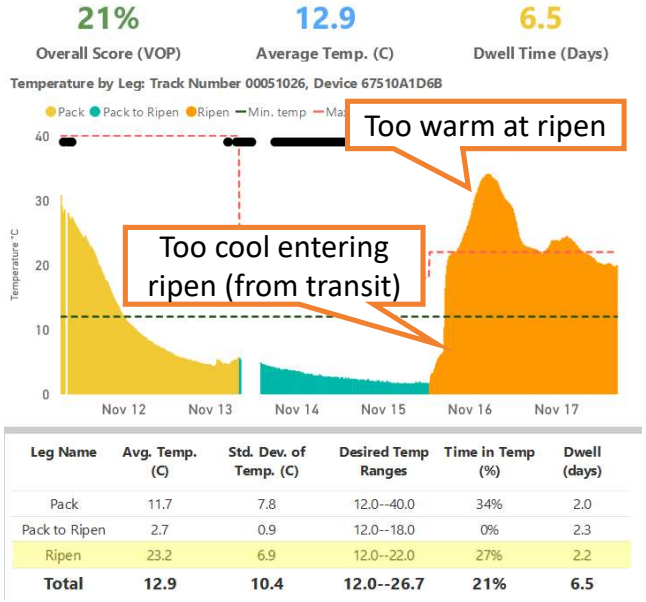
Ripening Leg Issues Examples



Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	25.1	2.2	12.0--40.0	100%	0.0
Pack to Ripen	19.7	0.7	12.0--18.0	0%	1.5
Ripen	26.6	2.2	12.0--22.0	6%	5.0
Total	**25.0**	**3.5**	**12.0--21.2**	**5%**	**6.6**



Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	17.1	4.7	12.0--40.0	100%	1.2
Pack to Ripen	7.5	2.0	12.0--18.0	2%	4.0
Ripen	10.5	1.1	12.0--22.0	2%	1.3
Total	**9.9**	**4.5**	**12.0--22.9**	**20%**	**6.5**



Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	11.7	7.8	12.0--40.0	34%	2.0
Pack to Ripen	2.7	0.9	12.0--18.0	0%	2.3
Ripen	23.2	6.9	12.0--22.0	27%	2.2
Total	**12.9**	**10.4**	**12.0--26.7**	**21%**	**6.5**

Warm load

- *Ripening averaged 26.6°C (max temp 30.1°C)*

Too cool load

- *Too cool at ripen may mean unripe mangoes at retail*
- *Ripening averaged 10.5°C*
- *Additional issues with too cool transit for this example*

Warm and too cool load

- *Entered ripening from a very cold transit leg (too cool ripen issue)*
- *Temperatures at ripen were too warm (max 33.1°C, average 23.2°C)*

WA seasons overview

- The only state where tracks worsened between seasons. However, this can be attributed to how few tracks there were in the 2019/20 season vs the 2020/21 season
- Even though tracks worsened, they still had the best scores overall when comparing grower states (WA, NT and QLD)
- 2020/21 season saw a rise in issues not seen in the 2019/20 season
  - e.g. pre cool failures and too cold tracks
- WA growers only sent to WA destinations
- Transit temperatures decreased between seasons

WA seasons

- VOP scores (% of time spent within optimal temp range) **decreased** from **Excellent** (92% 2019/20) to **Good** (81% 2020/21)
- Heat maps show more ‘amber’; or slightly out of temp dots in 2020/21 compared to the previous season
- Average temperature over the duration of the track **decreased by 0.3°C** in the 2020/21 season
- **4% decrease** in the number of tracks out of temp for more than 2hrs (red zone, 2019/20 40%, 2020/21 36%)

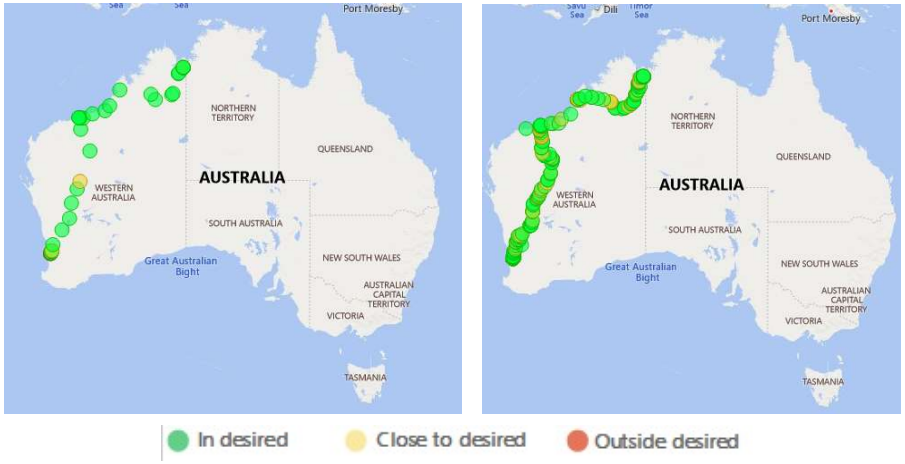
VOP Scores

- Perfect 100%
- Excellent 90-99%
- Good 80-89%
- Fair 70-79%
- Poor 60-69%
- Bad < 60%

All States	VOP	Average Temp °C	Average Dwell Time days	Average Time out of Temp (hrs)	# Tracks
Overall	85%	17 ± 1.8	7.1 ± 2.1	13	16
2019/20	92%	17.2 ± 0.4	7.8 ± 0.9	9.6	5
2020/21	81%	16.9 ± 2.1	6.7 ± 2.3	14.3	11

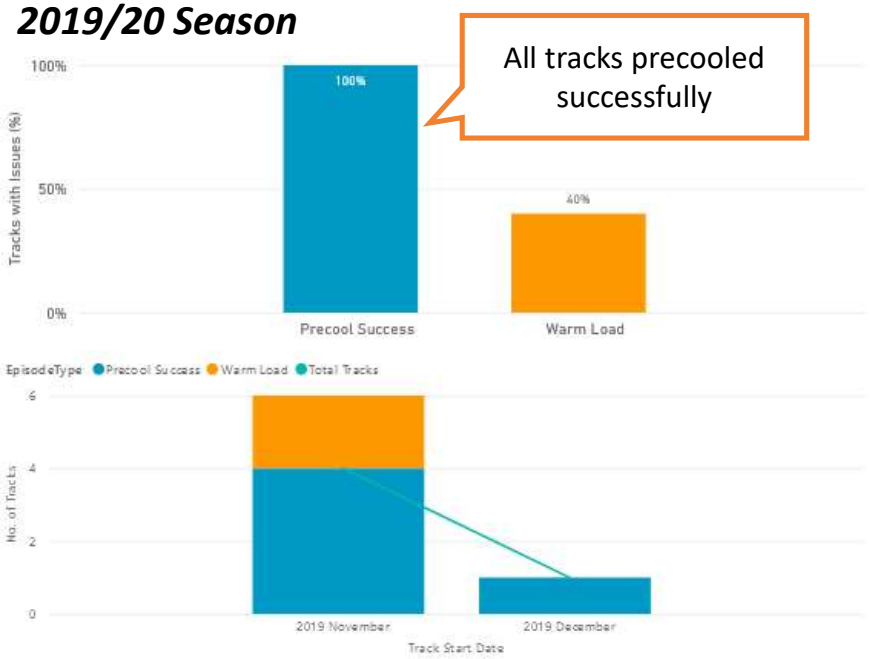
Above. *Overall voice of product (VOP) scores increased over tracking periods*

Below. *Heat maps of the WA 2019/20 season (left) and 2020/21 season (right)*

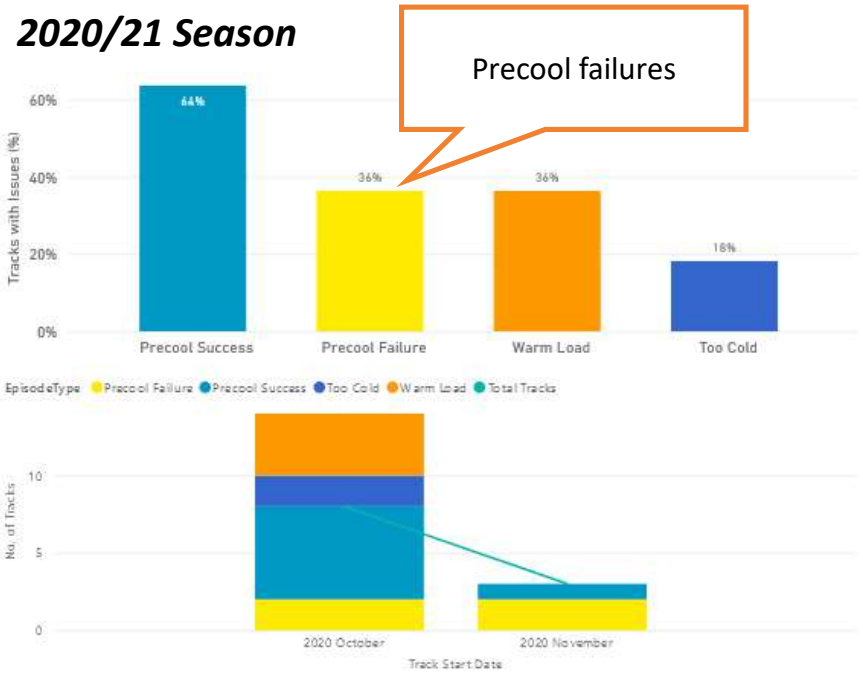


WA - Pack Leg Issues

2019/20 Season



2020/21 Season

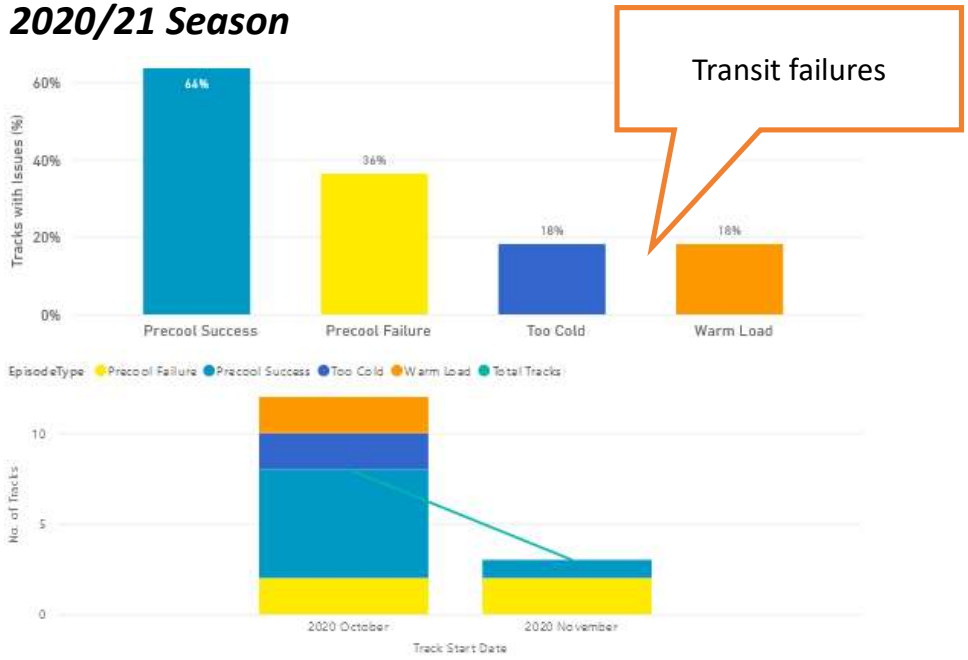


- Pre-cooling is critical to help preserve quality and prolong shelf life.
- Even if fruit is to be partially ripened in-transit, it should be cooled to 18°C, prior to dispatch.

WA - Pack to Ripen Leg Issues

2019/20 Season

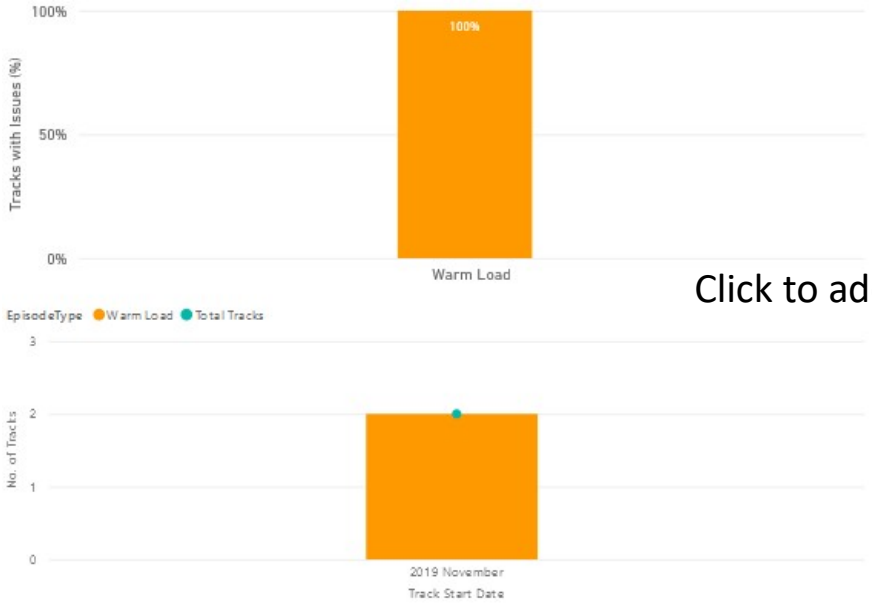
2020/21 Season



- 2019/20 season only had 5 tracks potentially why there were no visible transit failures (sample size too small)
  - Equal percentages of too cold and warming loads in 2020/21 season

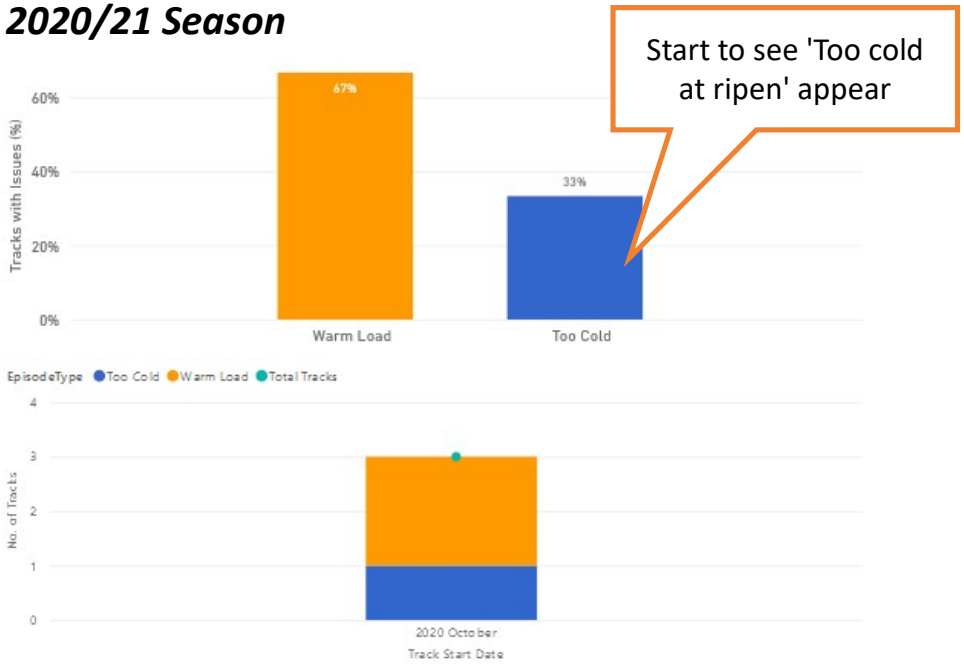
WA - Ripen Leg Issues

2019/20 Season



Click to add text

2020/21 Season

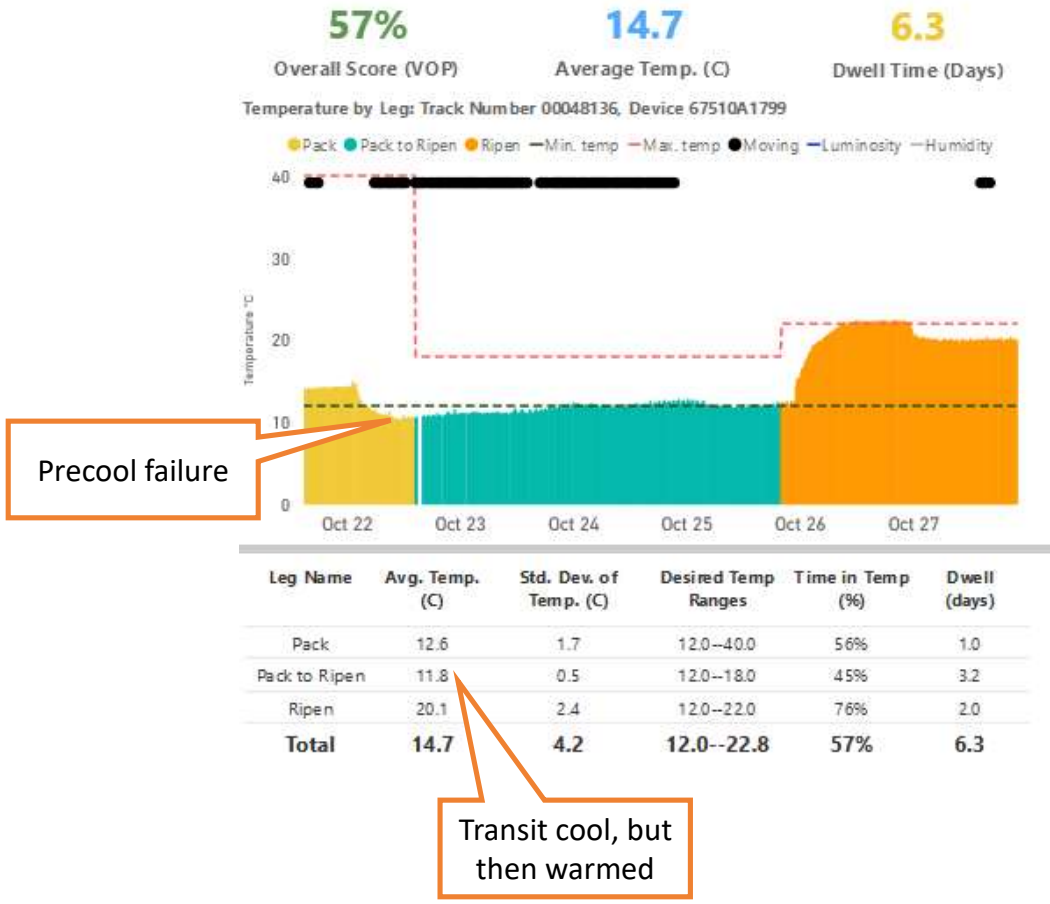


- 2019/20 season had ripening temps above the recommended ripening temps
- 2020/21 season saw some tracks being too cold at ripen. This was due to arrival at ripen too cold (too cool during transit)

WA - Route Issues

- WA Tracks always went to Perth
- 2020/21 tracks saw the appearance of issues.
  - perhaps due to more tracks than previous season
- Precool failures were mainly due to precooling too much (below 12°C)
- Tracks that experienced precool failure (too cool) also often had transits that were too cool.

2020/21 Season



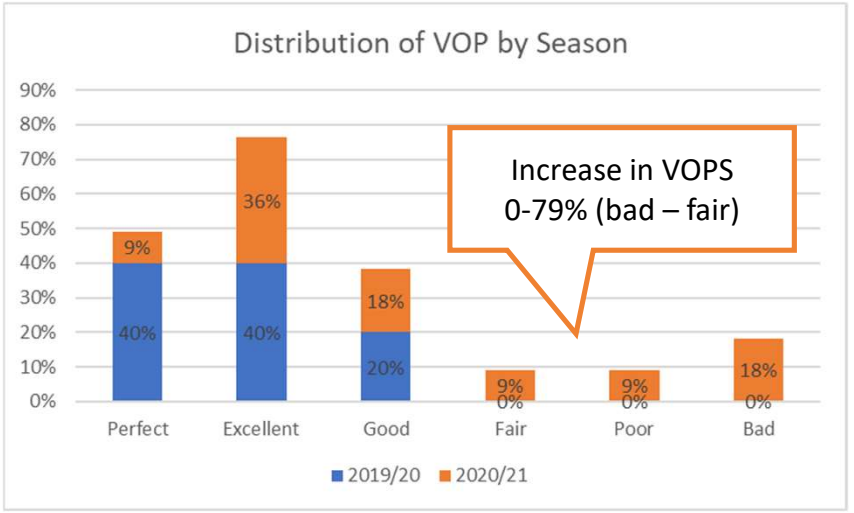
Leg Name	Avg. Temp. (C)	Std. Dev. of Temp. (C)	Desired Temp Ranges	Time in Temp (%)	Dwell (days)
Pack	12.6	1.7	12.0--40.0	56%	1.0
Pack to Ripen	11.8	0.5	12.0--18.0	45%	3.2
Ripen	20.1	2.4	12.0--22.0	76%	2.0
Total	**14.7**	**4.2**	**12.0--22.8**	**57%**	**6.3**

Transit cool, but then warmed

WA - VOP

2019/20 Season

2020/21 Season



- 2020/21 season **decrease** in **Perfect, Excellent and Good tracks**
- **31% decrease** in the number of **Perfect** tracks
- **36% increase** in the number tracks with a grade of **Fair** or below

WA – Tracks to each state

- WA Tracks only went to Perth
- Increase in number of transit legs spending more than 2hrs in red zone (**9%**)
- **Decrease** in average transit temperatures is good

2019-2020

2020-2021

WHOLE TRACK STATS	2019/20	2020/21
Total Tracks	5	11
Overall Average VOP	95%	93% ↓
Overall Average Temp C	17.2	17.3
Average Dwell Time days	7.8	6.7 ↓
# tracks >2hrs in red zone	40%	36% ↓
TRANSIT STATS	**2019/20**	**2020/21**
Total Tracks	5	11
Average Transit VOP	97%	90% ↓
Average Transit Temp	15.0	13.0 ↓
Average Transit Dwell Time days	1.7	2.4 ↑
Transit legs >2hrs in red zone	0%	9% ↑

NT seasons overview

- Tracks improved overall between the 2019/20 and 2020/21 seasons
- VOP scores **improved** significantly from **Bad** (59% 2019/20) to **Fair** (72% 2020/21)
- **8% decrease** in the number of tracks out of temp for more than 2hrs
- Overall temperatures during *transit* decreased (average decrease of **2.9ºC**), however, **too cool loads** during transit appeared in 2020/21
- Visual improvement in tracks transiting through Central Australia (NT to SA), tracks transiting along the VIC/NSW border and tracks travelling along the west coast of WA in the 2020/21 season

NT seasons

- VOP scores (% of time spent within optimal temp range) **improved** from **Bad** (59% 2019/20) to **Fair** (72% 2020/21)
- Heat maps show less 'red'; or out of temp dots in 2020/21 compared to the previous season
  - Particular improvements to WA and SA routes
- Average temperature over the duration of the track **decreased by 1.6°C** in the 2020/21 season
- **8% decrease** in the number of tracks out of temp for more than 2hrs (red zone, 2019/20 **83%**, 2020/21 **75%**)

VOP Scores

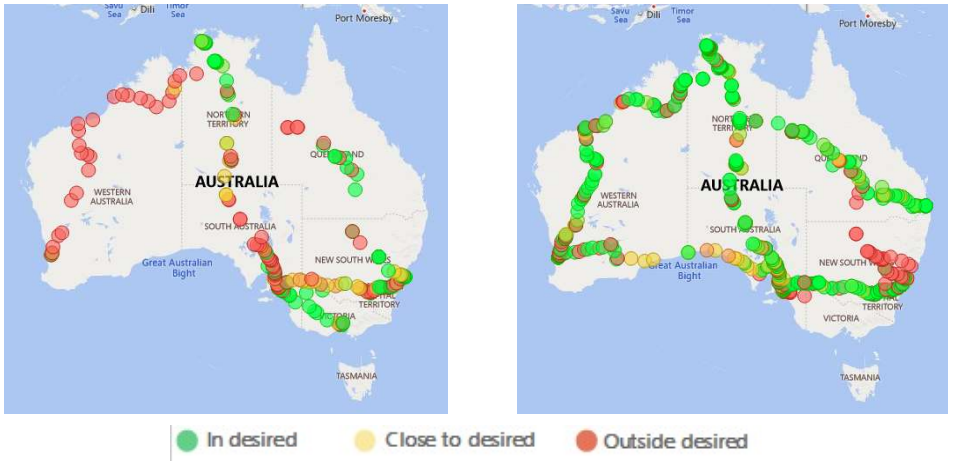
- Perfect 100%
- Excellent 90-99%
- Good 80-89%
- Fair 70-79%
- Poor 60-69%
- Bad < 60%

All States	VOP	Average Temp °C	Average Dwell Time days	Average Time out of Temp (hrs)	# Tracks
Overall	67%	18.4 ± 3.1	7.3 ± 2.5	29	59
2019/20	59%	19.3 ± 3.1	7.1 ± 2.8	35.5	23
2020/21	72%	17.7 ± 3.0	7.4 ± 2.2	24.9*	36

Above. *Overall voice of product (VOP) scores increased over tracking periods*

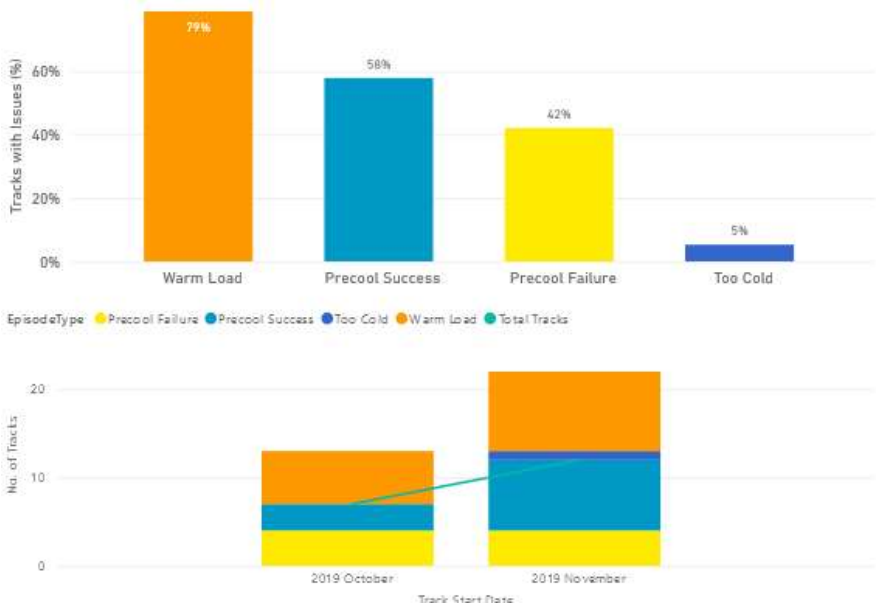
* This season had one pack house that was an outlier in terms of time spent out of temperature. When this packhouse was removed from the data, the average time spent out of temperature decreased to an average of **17.0** hours out of temperature for the 2020/21 season.

Below. *Heat maps of the NT 2019/20 season (left) and 2020/21 season (right)*

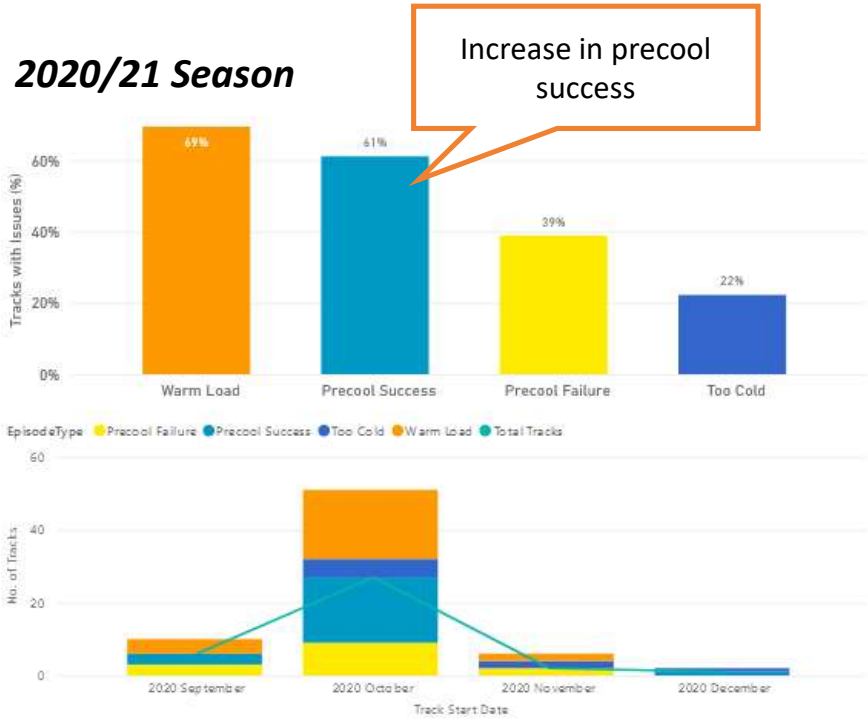


NT - Pack Leg Issues

2019/20 Season



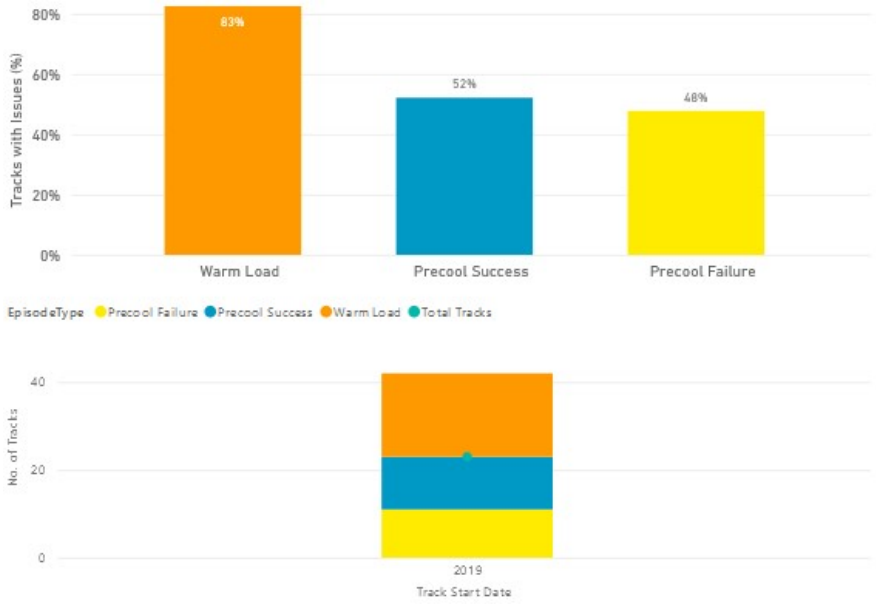
2020/21 Season



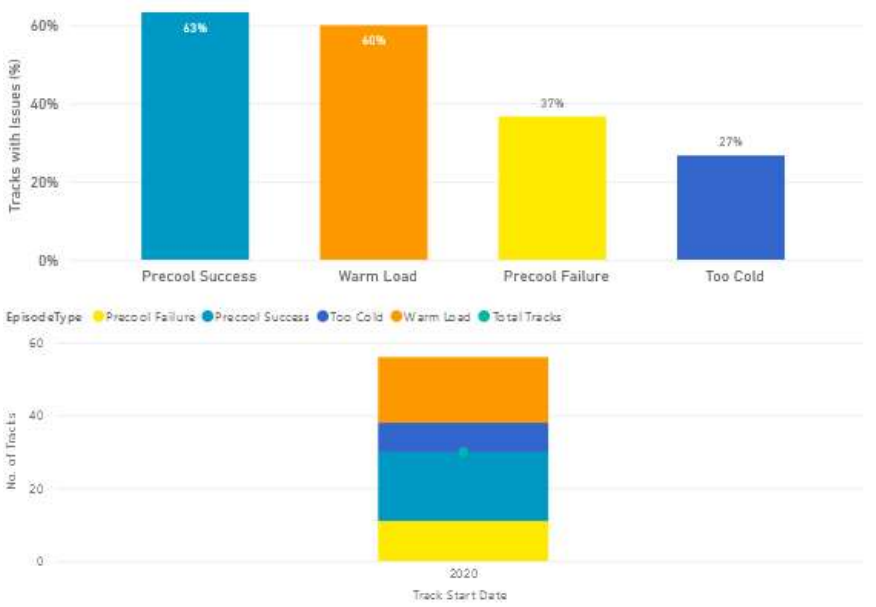
- Pre cool failures either not precooled, or precooled too much
- Pre-cooling is critical to help preserve quality and prolong shelf life.
- Even if fruit is to be partially ripened in-transit, it should be cooled to 18°C, prior to dispatch.

NT - Pack to Ripen Leg Issues

2019/20 Season



2020/21 Season



- Decrease in the number of warm loads but more too cold loads were being loaded out in 2020/21
  - More too cold loads may mean less ripening in transit occurring during the season

NT - Ripen Leg Issues

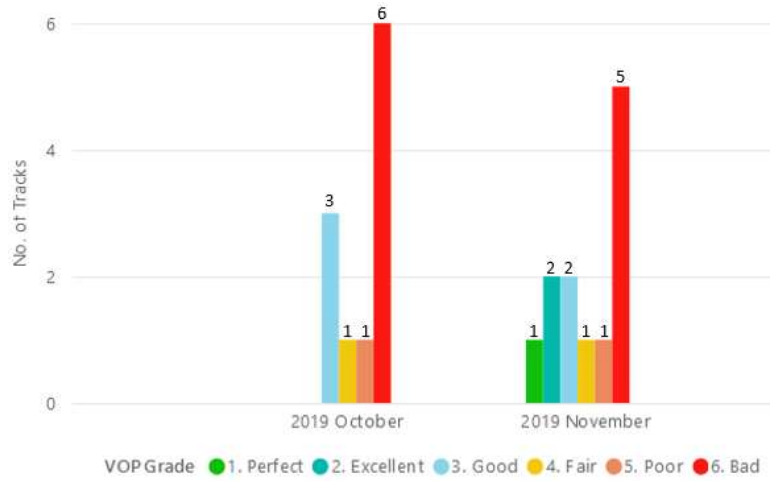
2019/20 Season

2020/21 Season

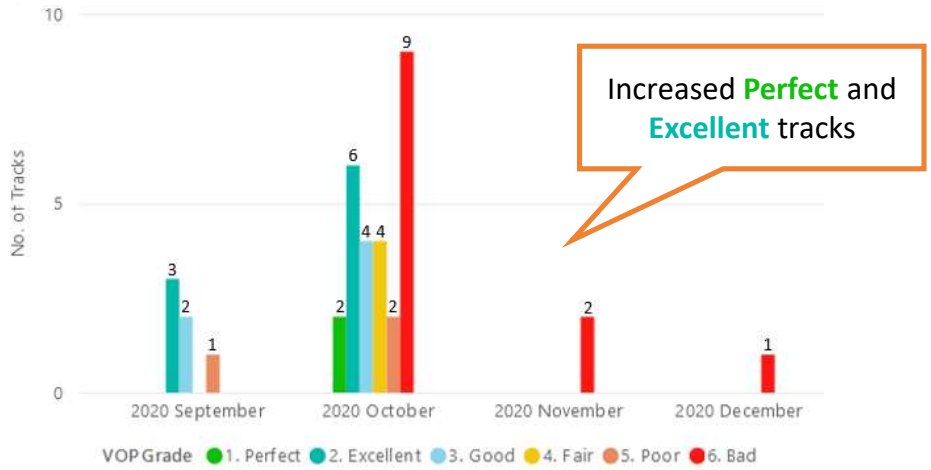
- 2019/20 season had ripening temps above the recommended ripening temps
- 2020/21 season saw some tracks being too cold at ripen. This was due to arrival at ripen too cold (too cool during transit)

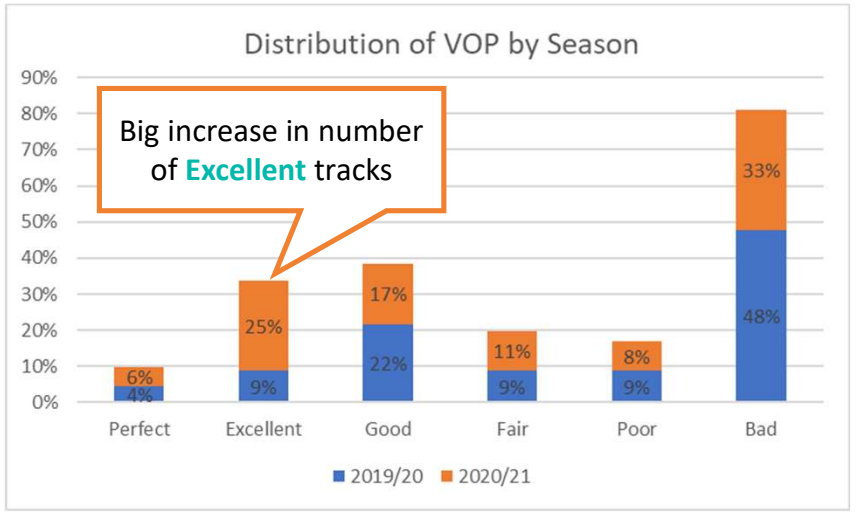
NT - VOP

2019/20 Season



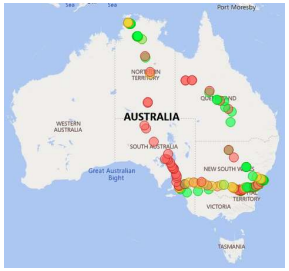
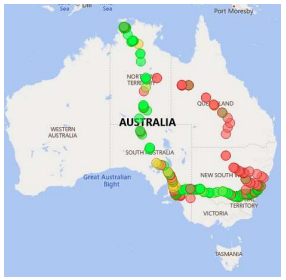
2020/21 Season





- 2020/21 season increase in **Perfect, Excellent and Fair tracks**
- **15% decrease** in the number of **Bad** tracks, but they still account for 33% of tracks
- **16% increase** in the number of **Excellent** tracks and they now count for 25% of overall tracks

NT – Tracks to each state

	WA	NSW	SA	QLD	VIC
2019-2020				n/a	
2020-2021					n/a

- Overall temperatures during *transit* decreased (average decrease of **2.9ºC**)
- **23% increase** in the average VOP scores of tracks in the 2020/21 season as previously discussed
- Visual improvement in tracks transiting through Central Australia (NT to SA), tracks transiting along the VIC/NSW border and tracks travelling along the west coast of WA in the 2020/21 season
- Tracks to QLD only occurred in 2020/21 and tracks to VIC only occurred during the 2019/20 season

NT – Tracks to each state

	WA		NSW		SA		QLD		VIC	
WHOLE TRACK STATS	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
Total Tracks	2	8	15	21	2	2	0	5	4	0
Overall Average VOP	60%	**75%** ↑	59%	73%	83%	99%	n/a	91%	79%	n/a
Overall Average Temp C	20.5	19.1	19.7	**17.3** ↓	15.8	17.8		17.2	19.1	
Average Dwell Time days	8.0	7.3	6.4	**7.5**	10.7	5.3		7.3	7.4	
# tracks >2hrs in red zone	100%	100%	87%	76%	100%	**0%** ↓		80%	50%	
TRANSIT STATS	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
Average Transit VOP	26%	**67%** ↑	47%	50%	47%	50%		87%	79%	
Average Transit Temp	21.5	18.7	19.8	**16.9**	19.8	**16.9**		16.0	17.9	
Average Transit Dwell Time days	1.8	**4.6**	4.5	3.0	4.5	3.0		4.3	3.5	
Transit legs >2hrs in red zone	100%	**75%** ↓	85%	76%	85%	76%		80%	100%	

- Transit to WA, biggest **improvement overall in tracks during the 2020/21 season**
- Tracks to NSW had the biggest improvements in overall temperature **decreasing by 2.4ºC**
- Average transit VOPs to all end states **improved by 157%**
- Overall transit temperatures decreased by 2.9ºC to every end state contributing to less transit legs spending time in the red temperature zone during the 2020/21 season

QLD seasons overview

- Tracks improved overall between the 2019/20 and 2020/21 seasons
- VOP scores **increased** from Poor (68% 2019/20) to Fair (79% 2020/21)
  - *One VOP grade increase*
- **11% decrease** in the number of tracks out of temp for more than 2hrs
  - *The largest improvement of all the states*
- More excellent and perfect VOP graded tracks in the 2020/21 season
- Tracks from QLD growers to NSW showed the greatest overall improvements in temperature control, while tracks from QLD growers to QLD destinations had the biggest improvements in transit controls

QLD seasons

- VOP scores (% of time spent within optimal temp range) **increased** from Poor (68% 2019/20) to Fair (79% 2020/21)
- Heat maps show slightly less 'red'; or out of temp dots in 2020/21 compared to the previous season
- Average temperature over the duration of the track **decreased by 1.1°C** in the 2020/21 season
- **11% decrease** in the number of tracks out of temp for more than 2hrs (red zone, 2019/20 76%, 2020/21 65%)
  - Biggest improvement in time spent out of temp

VOP Scores

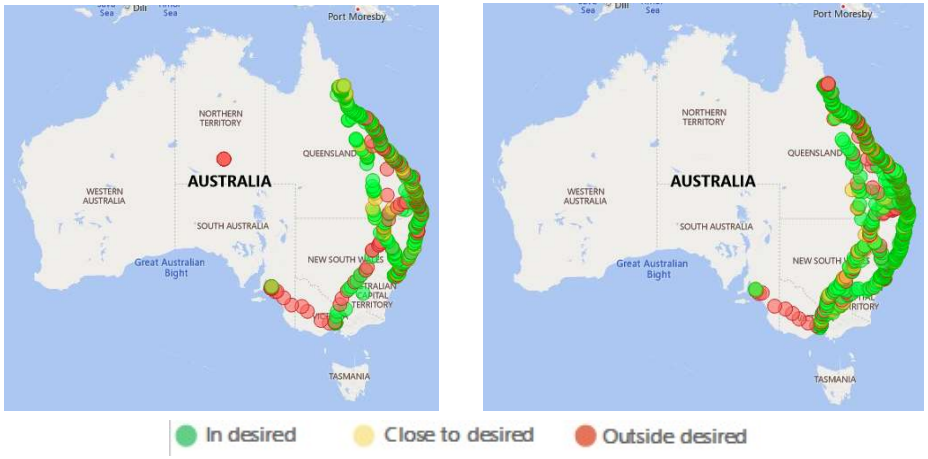
- Perfect 100%
- Excellent 90-99%
- Good 80-89%
- Fair 70-79%
- Poor 60-69%
- Bad < 60%

All States	VOP	Average Temp °C	Average Dwell Time days	Average Time out of Temp (hrs)	# Tracks
Overall	77%	17.7 ± 3.3	9.8 ± 6.2	40.1	107
2019/20	68%	18.5 ± 3.6	7.4 ± 4.1	28.8	50
2020/21	79%	17.4 ± 2.9	11.9 ± 6.8	50.2*	57

Above. *Overall voice of product (VOP) scores increased over tracking periods*

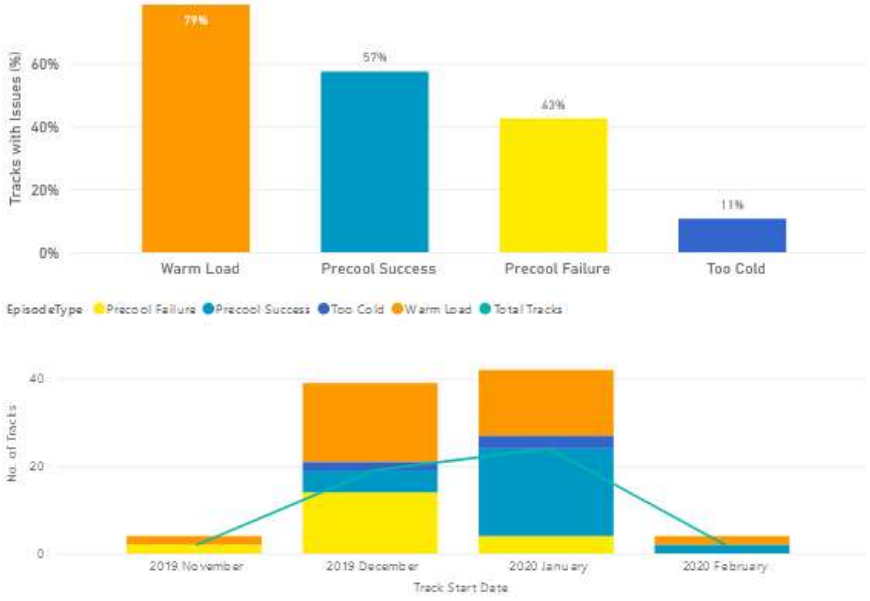
* This season had one pack house that was an outlier in terms of time spent out of temperature. When this packhouse was removed from the data, the average time spent out of temperature decreased to an average of **23.1** hours out of temperature for the 2020/21 season.

Below. *Heat maps of the NT 2019/20 season (left) and 2020/21 season (right)*



QLD - Pack Leg Issues

2019/20 Season

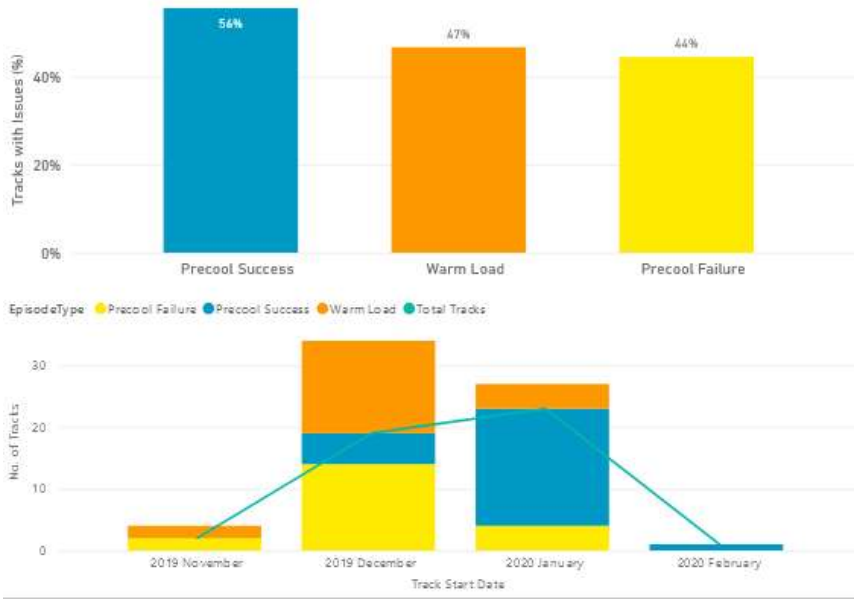


2020/21 Season

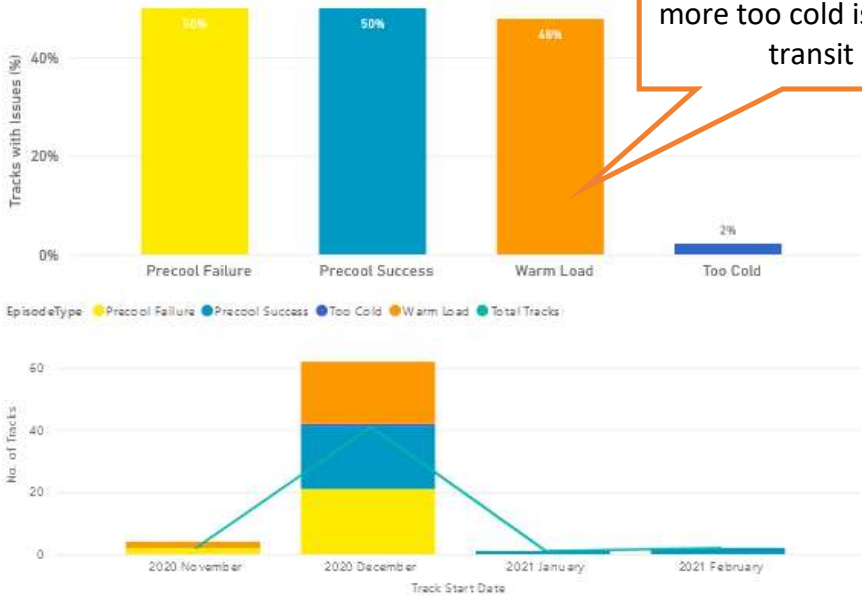
- Pre cool failures in 2019/20 either not precooled, or precooled too much
- Pre cool failures in 2020/21 season more often due to not precooling before loadout

QLD - Pack to Ripen Leg Issues

2019/20 Season



2020/21 Season

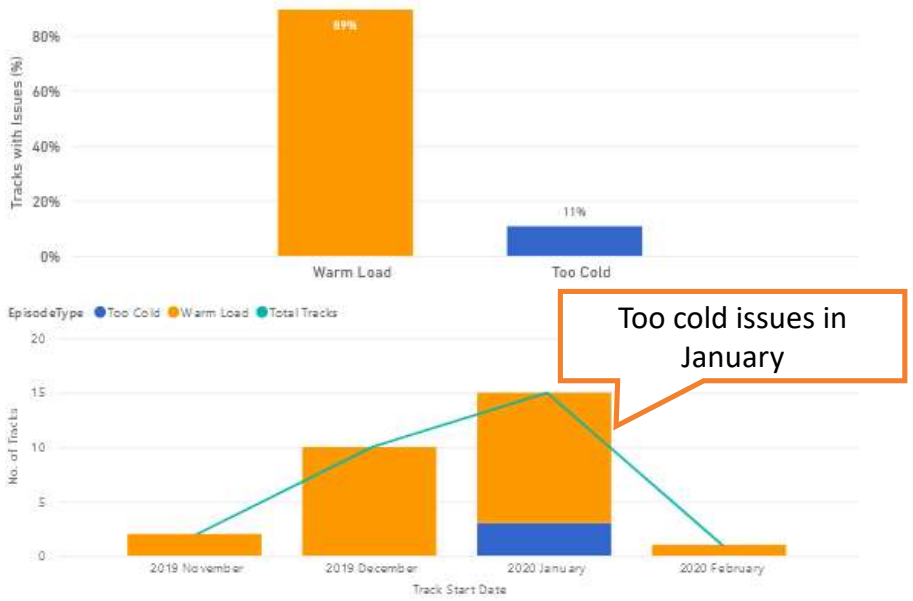


Slight increase in warming loads and more too cold issues in transit

- More issues in transit with warming loads and too cold loads in 2020/21
- Pre cool failures in 2020/21 season more often due to not precooling before loadout

QLD - Ripen Leg Issues

2019/20 Season

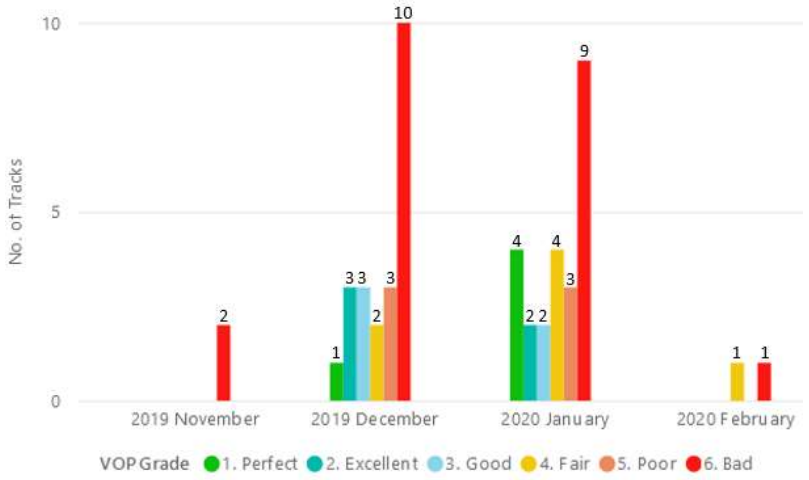


2020/21 Season

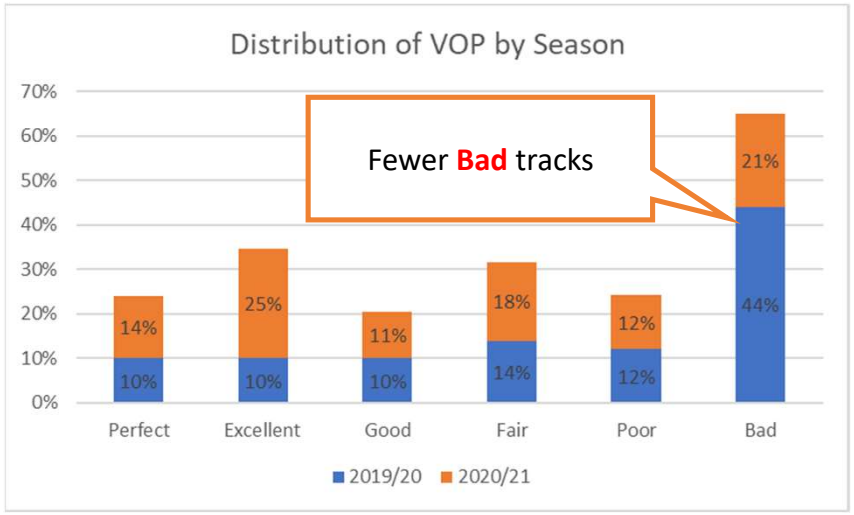
- 2019/20 season had too cold issues at ripen in January. Perhaps this was because of outside temps at that time
- 2020/21 season saw only warming issues at ripen.

QLD - VOP

2019/20 Season

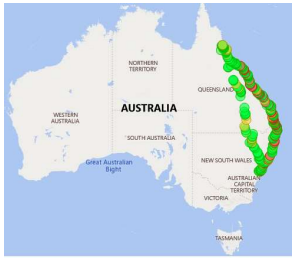
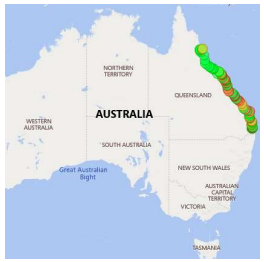
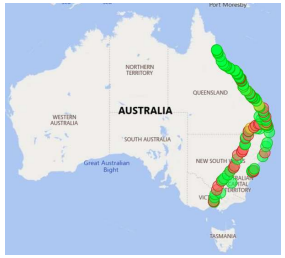
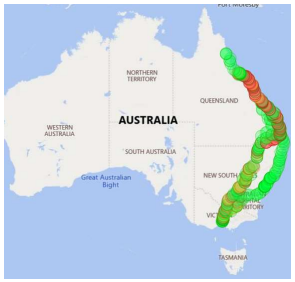


2020/21 Season



- 2020/21 season increase in **Perfect, Excellent, Good and Fair tracks**
- **23% decrease** in the number of **Bad** tracks, but they still account for 21% of tracks
- **Excellent** tracks now make up the majority of tracks (25%) with a **15% increase**
- **Perfect** tracks also **increased by 4%**

QLD – Tracks to each state

	WA	NSW	SA	QLD	VIC
2019-2020	n/a				
2020-2021	n/a				

- Overall temperatures during *transit* only decreased by an average of 0.1^{o}C
- Tracks ending in NSW made up the majority of tracks from QLD growers.
- Visual improvement in tracks to SA and QLD, although SA only had 2 tracks total over both seasons
- Tracks within QLD had the biggest improvements in transit scores, while tracks to NSW had the largest improvement in overall scores

QLD – Tracks to each state

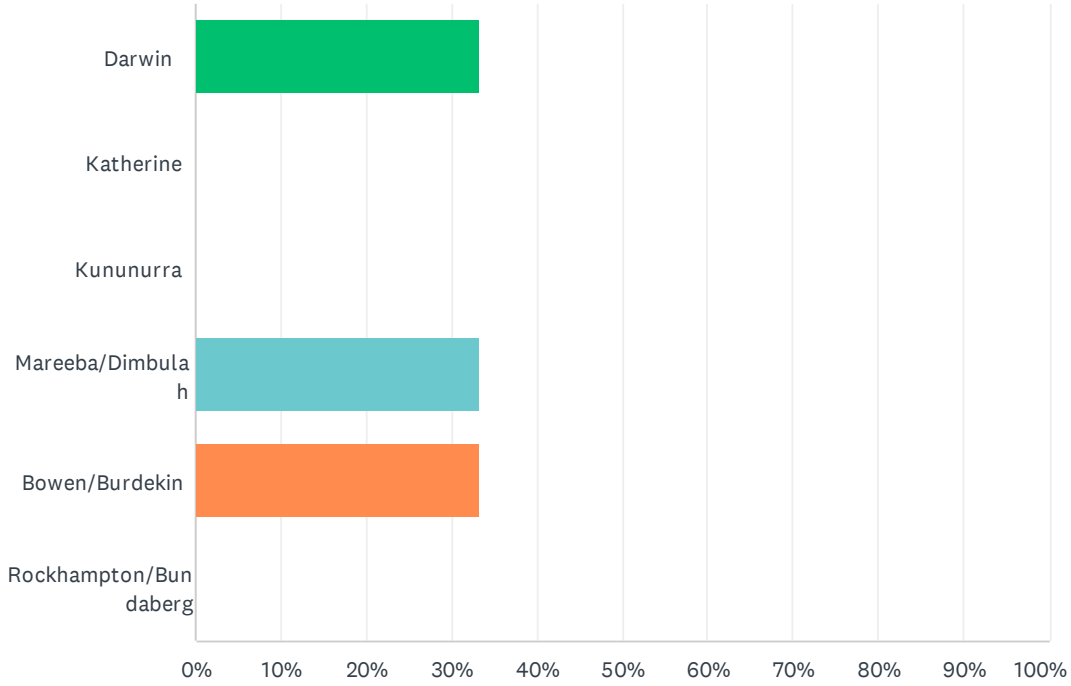
	WA		NSW		SA		QLD		VIC	
WHOLE TRACK STATS	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
Total Tracks	n/a	n/a	27	28	1	1	13	12	8	14
Overall Average VOP			66%	**78%** ↑	54%	62%	78%	92%	78%	79%
Overall Average Temp C			20.0	18.7	17.1	18.5	20.2	**18.5** ↓	16.9	18.3
Average Dwell Time days			7.7	13.2	16.0	4.5	4.6	9.6	9.6	10.2
# tracks >2hrs in red zone			81%	**64%** ↓	100%	100%	64%	50%	75%	79%

TRANSIT STATS	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**
Average Transit VOP	n/a	n/a	68%	77%	54%	62%	64%	**80%** ↑	64%	53%
Average Transit Temp			18.2	17.2	17.1	18.5	19.1	**17.2** ↓	18.0	18.7
Average Transit Dwell Time days			3.0	3.8	16.0	4.5	1.2	3.6	3.5	5.1
Transit legs >2hrs in red zone			42%	46%	100%	100%	38%	**0%** ↓	50%	77%

- QLD tracks to NSW had the biggest increase in overall VOP, resulting in a decrease in the number of tracks in the red zone
- Tracks within QLD showed the largest improvement in transit, increasing the average transit VOP and decreasing the average transit temperatures
- QLD transits in the 2020/21 season had **zero tracks spending more than 2 hrs in the red temperature zone**

Q1 Which region is your property located in?

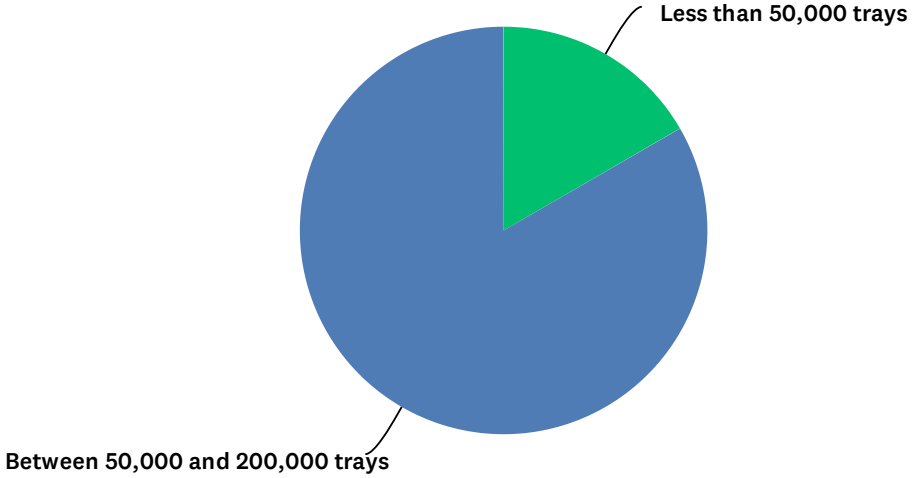
Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Darwin	33.33%	2
Katherine	0.00%	0
Kununurra	0.00%	0
Mareeba/Dimbulah	33.33%	2
Bowen/Burdekin	33.33%	2
Rockhampton/Bundaberg	0.00%	0
TOTAL		6

Q2 What is the average number of trays (7kg eq) produced per year?

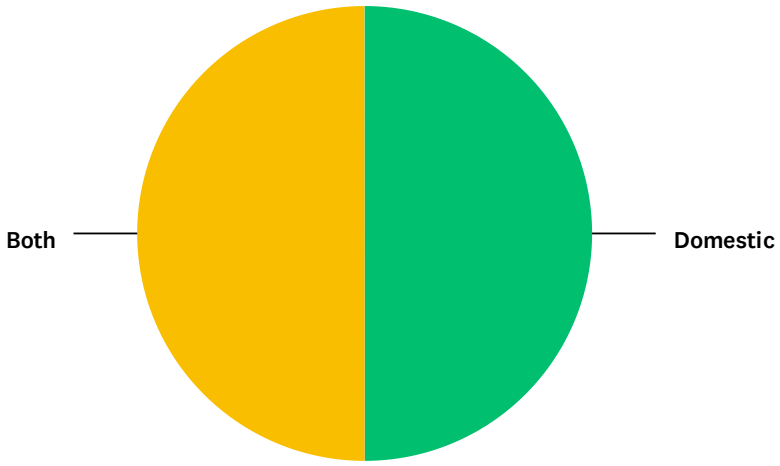
Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Less than 50,000 trays	16.67%	1
Between 50,000 and 200,000 trays	83.33%	5
More than 200,000 trays	0.00%	0
Prefer not to say	0.00%	0
TOTAL		6

Q3 Do you supply domestic or export markets?

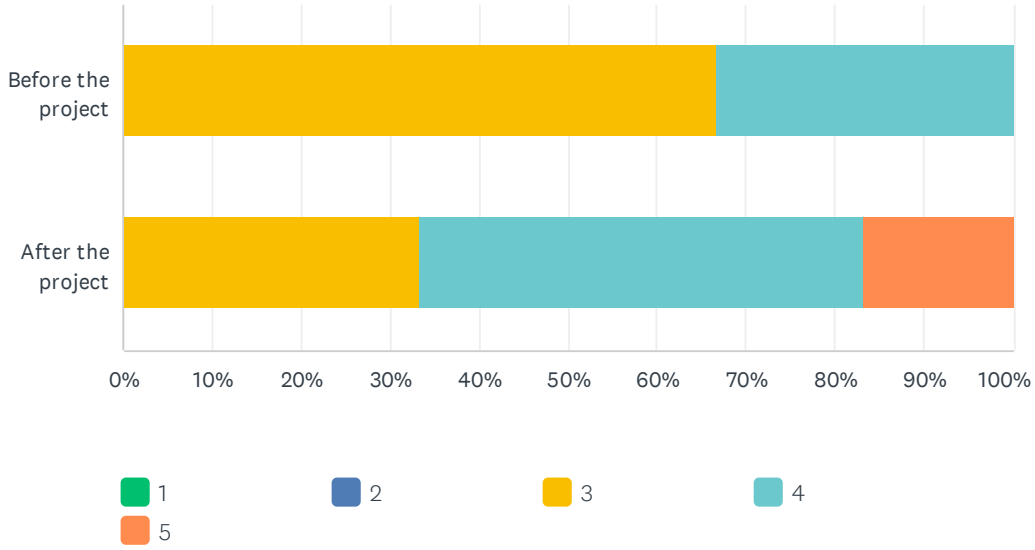
Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Domestic	50.00%	3
Export	0.00%	0
Both	50.00%	3
TOTAL		6

Q4 Please rate your knowledge of temperature management throughout the supply chain (from 1 to 5, 1 being very poor and 5 being excellent)

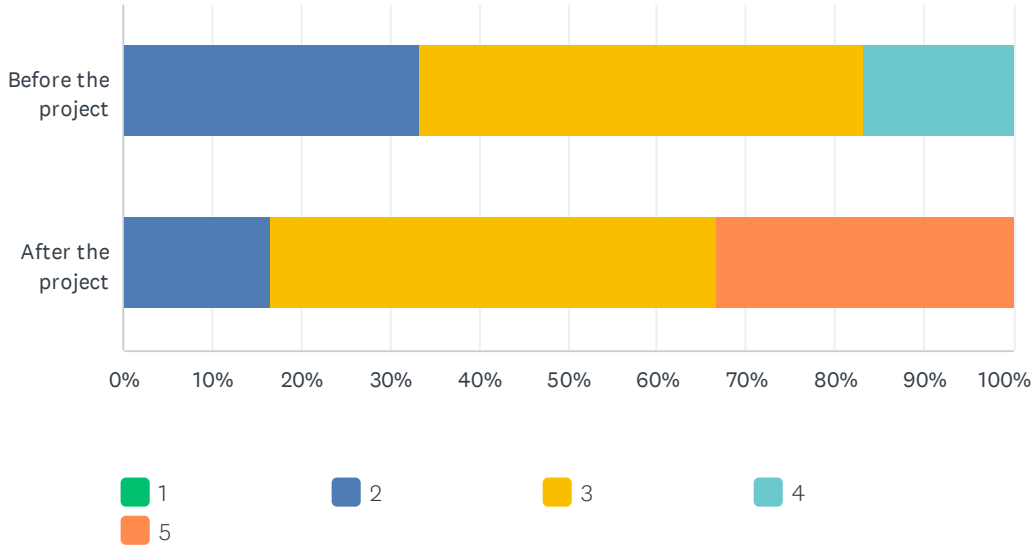
Answered: 6 Skipped: 0



	1	2	3	4	5	TOTAL	WEIGHTED AVERAGE
Before the project	0.00% 0	0.00% 0	66.67% 4	33.33% 2	0.00% 0	6	3.33
After the project	0.00% 0	0.00% 0	33.33% 2	50.00% 3	16.67% 1	6	3.83

Q5 Please rate your confidence on your supply chains' performance (from 1 to 5, 1 being very poor and 5 being excellent).

Answered: 6 Skipped: 0



	1	2	3	4	5	TOTAL	WEIGHTED AVERAGE
Before the project	0.00% 0	33.33% 2	50.00% 3	16.67% 1	0.00% 0	6	2.83
After the project	0.00% 0	16.67% 1	50.00% 3	0.00% 0	33.33% 2	6	3.50

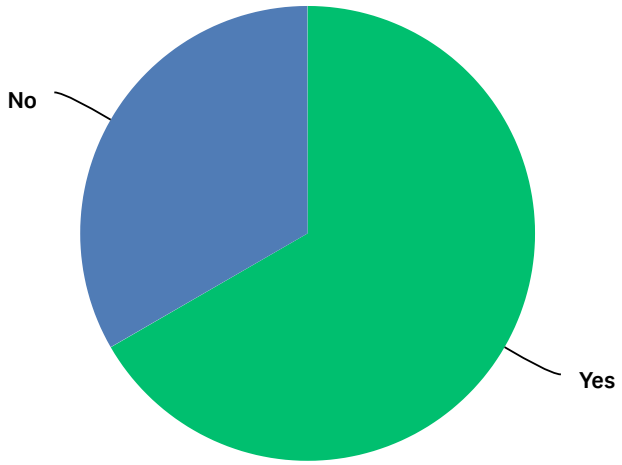
Q6 What are some of the reasons you gave this score?

Answered: 4 Skipped: 2

#	RESPONSES	DATE
1	Very little feedback	2/18/2022 6:29 PM
2	Temp were higher than expected	2/16/2022 9:20 PM
3	Some Truck Company contiune to uses refrigrated tauliner trailer on long hual refregration to Sydney market instead of pantech trailer. They still think there is no different in tempature control on these truck instead of what we know now, refuse to listen to our complain and evidence. They say, this all we have, take it or leave it.	2/3/2022 11:42 PM
4	I’m with a new transport company	2/2/2022 5:58 PM

Q7 Had you used temperature data loggers before being involved in the project?

Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	66.67%	4
No	33.33%	2
TOTAL		6

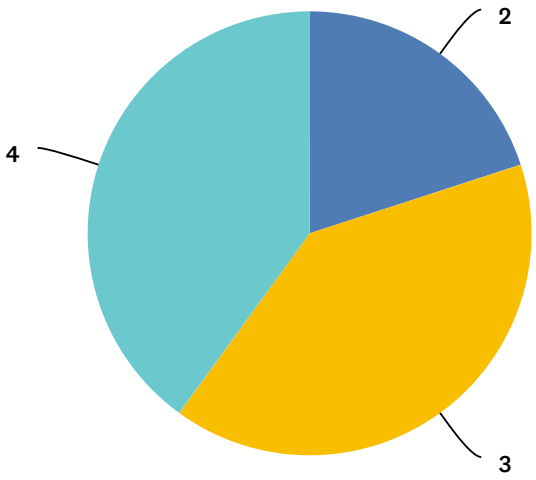
Q8 If yes, what type of trackers had you used?

Answered: 4 Skipped: 2

#	RESPONSES	DATE
1	Only when fruit need Insurence claims	2/18/2022 6:29 PM
2	Unsure was from another project many years ago	2/16/2022 9:20 PM
3	USB single trip logger and USB reuseable tempature loggers	2/3/2022 11:42 PM
4	Ericsson	2/2/2022 5:58 PM

Q9 Overall, how would you rate your involvement in the Escavox supply chain project?(scale from 1 to 5, 1 being not valuable to 5 being extremely valuable)

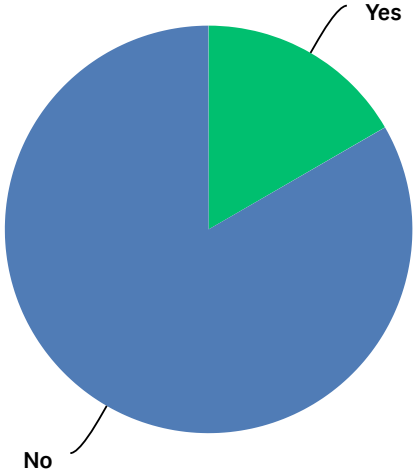
Answered: 5 Skipped: 1



ANSWER CHOICES	RESPONSES	
1	0.00%	0
2	20.00%	1
3	40.00%	2
4	40.00%	2
5	0.00%	0
TOTAL		5

Q10 Have you implemented any changes as a result of being involved in the project?

Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	16.67%	1
No	83.33%	5
TOTAL		6

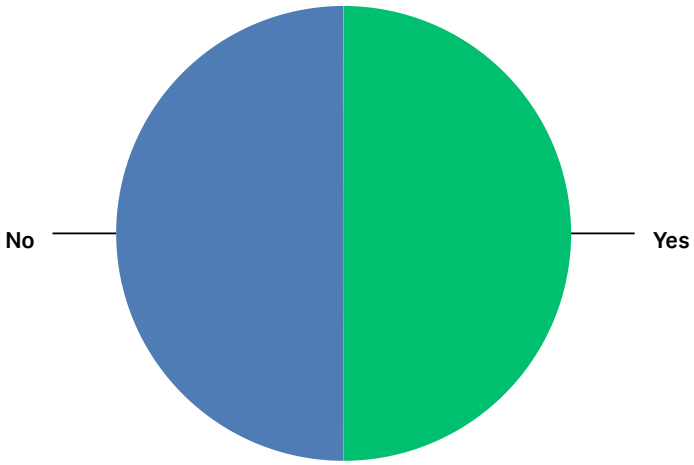
Q11 If yes, what are the changes you have made? (i.e. change transporters, pre-cooling practices, etc)

Answered: 1 Skipped: 5

#	RESPONSES	DATE
1	Change transport company	2/2/2022 5:58 PM

Q12 Will you keep monitoring the temperature of your consignments in the future?

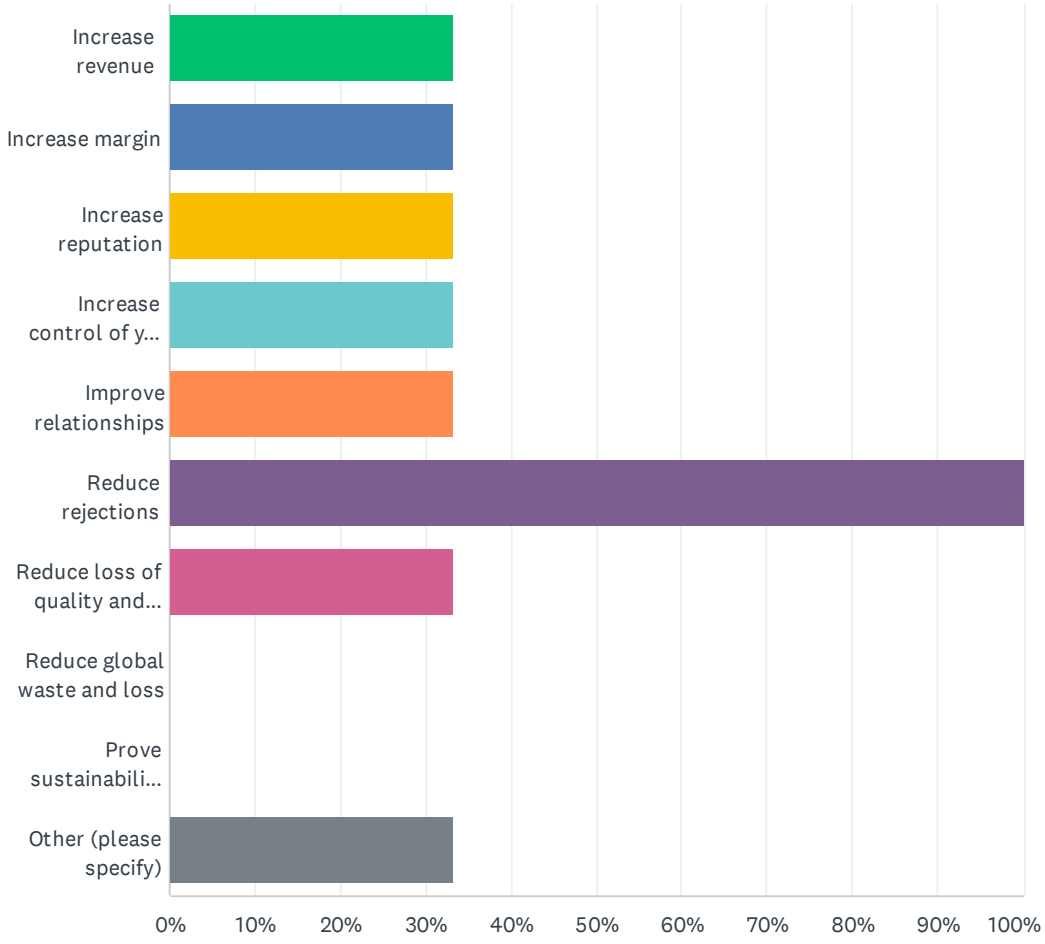
Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	50.00%	3
No	50.00%	3
TOTAL		6

Q13 If yes, why? Please select all that apply.

Answered: 3 Skipped: 3

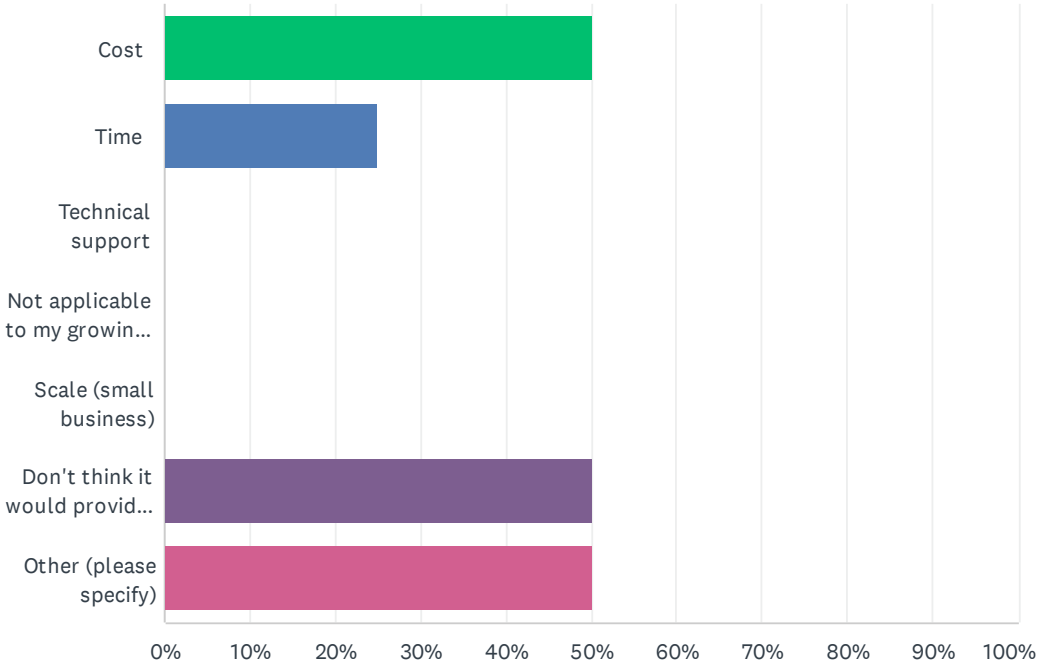


ANSWER CHOICES	RESPONSES	
Increase revenue	33.33%	1
Increase margin	33.33%	1
Increase reputation	33.33%	1
Increase control of your supply chain	33.33%	1
Improve relationships	33.33%	1
Reduce rejections	100.00%	3
Reduce loss of quality and shelf life	33.33%	1
Reduce global waste and loss	0.00%	0
Prove sustainability of your supply chain	0.00%	0
Other (please specify)	33.33%	1
Total Respondents: 3		

#	OTHER (PLEASE SPECIFY)	DATE
1	Insurance	2/2/2022 5:58 PM

Q14 If no, why not? Please select all that apply.

Answered: 4 Skipped: 2



ANSWER CHOICES	RESPONSES	
Cost	50.00%	2
Time	25.00%	1
Technical support	0.00%	0
Not applicable to my growing region/climate	0.00%	0
Scale (small business)	0.00%	0
Don't think it would provide benefits/improvements	50.00%	2
Other (please specify)	50.00%	2
Total Respondents: 4		

#	OTHER (PLEASE SPECIFY)	DATE
1	Inability for a grower to control how transport companies and outside parties handle fruit temperatures temperatures.	2/16/2022 9:20 PM
2	Trucking company won't listen anyway to your complains about tempature.	2/3/2022 11:42 PM

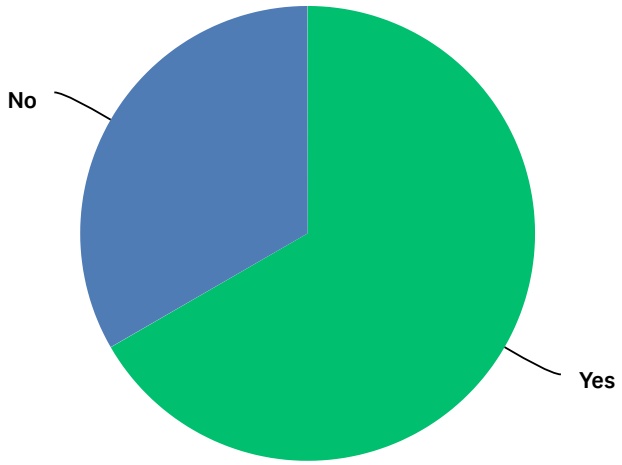
Q15 Any other comments/notes?

Answered: 2 Skipped: 4

#	RESPONSES	DATE
1	I do fully agree the importance of a grower to understand how their produce is handled including tempreture. Unfortunately there would be difficulties in making outside parties comply to your requirements. Ultimately a grower must decide which company serves them best, but a number of factors influence this decision, temperature control would be 1.	2/16/2022 9:20 PM
2	The Industry need to take these trucking company to account for their trucks and their service standard. We only have one company supply direct to sydney. They monoplise this route and provide substandal service. Can't go anywhere else as other routes are over stretch due to season. IE rail/road to Adel.	2/3/2022 11:42 PM

Q16 AMIA would like to develop some case studies. Do you agree to be contacted by the Escavox team to further discuss your experience?

Answered: 6 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	66.67%	4
No	33.33%	2
TOTAL		6

2018/2019 FORECAST — DISPATCH TO THE MARKETS
UPDATED 19 MARCH 2019

ACTUAL TRAYS DISPATCHED TO MARKET FROM CARNARVON AND GINGIN: 14,000

DARWIN (2.2 million trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP		0.5%	0.5%	1%	2%	5%	9%	16%	19.5%	21%	18%	5%	2%	0.5%																				
R2E2			0.5%	1%	0.5%	1%	9%	6%	19%	15%	8%	32%	8%																					
CALYPSO									6.5%	23%	29%	23.5%	18%																					
OTHER					2%	9%	15%	22%	7%	12%	4%	10%	6%	5%	7%	1%																		
VOLUME* (7 kg trays 000s)		5	6	23	31	86	184	274	381	457	401	243	117	4	4	0.5																		

KATHERINE/MATARANKA (2.3 million trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP									0.5%	1%	19%	8%	28%	23%	7%	0.5%	7%	3.5%	2%	0.5%	0.5%														
R2E2											1%	8%	19%	25%	5%	5%	11%	12.5%	13%	0.5%	3%														
CALYPSO												1%	3%	17%	17%	18.5%	21.5%	20%	2%																
HONEY GOLD															9%	18%	24%	13%	36%																
OTHER											16%	63%								21%	40%														
VOLUME* (7 kg trays 000s)									2	8	135	103	282	420	266	247	339	304	156	6	19														

KUNUNURRA (323 thousand trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP							0.5%	0.5%	0.5%	0.5%	2%	3%	14%	19%	1%	20%	20%	19%																
R2E2											0.5%	5%	16%	21.5%	3%	12%	21%	21%																
VOLUME* (7 kg trays 000s)							1	1	1	1	4	12	48	64	4	57	65	65																

BOWEN/BURDEKIN (1.3 million trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP														1%	6%	11%	25%	23%	12%	7%	9%	6%												
R2E2													1%	7%	8%	14%	13%	22%	16%	12%	3%	4%												
HONEY GOLD																			22%	18%	33%	23%	4%											
VOLUME* (7 kg trays 000s)													5	54	98	150	212	280	197	137	100	75	3											

MAREEBA/DIMBULAH (2.6 million trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP																0.5%	3%	5.5%	21.5%	25%	27.5%	12.5%	3%	1.5%										
R2E2																	2%	6.5%	7%	25.5%	35%	13%	10%	0.5%	0.5%									
CALYPSO																			12%	27%	23%	15%	15%	8%										
HONEY GOLD																				4%		18%	23.5%	30.5%	21%	3%								
KEITT																								6.5%	11%	18%	1%		21%	27%	15.5%			
OTHER																						5%	9%	21%	19%	2%	5%		5%	9%	16%	9%		
VOLUME* (7 kg trays 000s)																5	38	72	325	529	545	322	239	181	92	38	10	0	42	59	50	14		

SOUTH QUEENSLAND (618 thousand trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP																				3%	6%	5%	17%	17%	28%	18%	6%							
R2E2																			2%	6%	11%	12%	24%	5%	6%	8%	25%	1%						
CALYPSO																								15%	44%	31%	10%							
HONEY GOLD																					2.5%	7.5%	9%	1%	21%	18%	24.5%	5%	6%	1%	4.5%			
KEITT																										50%	8%	14%	16%	4.5%	7.5%			
OTHER																							16%	19%	11%	51%		3%						
VOLUME* (7 kg trays 000s)																			2	9	21	31	58	56	162	141	97	17	17	4	3			

CARNARVON (122 thousand trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP																								7%	43%	49%	1%							
R2E2																				11%	18%	19%	19%	13%	13%		7%							
HONEY GOLD																										2%	6%	5%	18%	27%	13%	18%	11%	
KEITT																													52%	48%				
OTHER																										40%		24%	36%					
VOLUME* (7 kg trays 000s)																				3	5	5	5	4	9	11	6	6	18	20	9	13	8	

GINGIN (23 thousand trays)

WEEK ENDING (Friday)	03 AUG	10 AUG	17 AUG	24 AUG	31 AUG	07 SEP	14 SEP	21 SEP	28 SEP	05 OCT	12 OCT	19 OCT	26 OCT	02 NOV	09 NOV	16 NOV	23 NOV	30 NOV	07 DEC	14 DEC	21 DEC	28 DEC	04 JAN	11 JAN	18 JAN	25 JAN	01 FEB	08 FEB	15 FEB	22 FEB	01 MAR	08 MAR	15 MAR	22 MAR
KP																															26%	30%	20%	24%
R2E2																																	60%	40%
VOLUME* (7 kg trays 000s)																															5	6	6	6

***BLACK - Actual weekly volume of trays dispatched from the region across all varieties**
***RED - Forecast weekly volume of trays dispatched from the region across all varieties**

2019/2020 FORECAST — DISPATCH TO THE MARKETS
UPDATED 24 MARCH 2020

ACTUAL TRAYS DISPATCHED TO MARKET: 1,000

TOTAL FOR ALL BELOW REGIONS AND VARIETIES (8.9 million trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR	TOTAL
CLASS 1 TOTAL	1	1	5	6	8	5	10	16	31	54	62	83	127	240	254	333	397	292	407	311	297	379	394	309	294	325	324	367	265	197	151	122	38	19	14	14	10	1	6163
CLASS 2 TOTAL	0	0	1	3	3	3	5	11	20	32	42	48	82	143	152	203	202	129	180	138	84	77	82	78	108	101	83	103	64	42	51	46	20	8	13	9	3	0	2369
OTHER TOTAL	0	1	0	1	3	5	9	2	8	15	20	11	12	24	19	19	21	23	44	34	9	4	2	5	8	5	1	0	5	15	1	15	2	4	0	0	7	0	354
TOTAL VOLUME* (7 KG TRAYS 000S)	1	2	6	10	14	13	24	29	59	101	124	142	221	407	425	555	620	444	631	483	390	460	478	392	410	431	408	470	334	254	203	183	60	31	27	23	20	1	8886

DARWIN (3.1 million trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1	0.1%	0.1%	0.4%	0.5%	0.7%	0.4%	0.7%	1.3%	2.5%	4.4%	4.7%	5.9%	8.8%	14.2%	15.8%	17%	12.6%	4.6%	3.9%	1.6%	0.1%																		
R2E2 CLASS 1	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.6%	0.0%	0.5%	0.4%	2.2%	5.5%	6.1%	21.5%	6.6%	7.4%	32.3%	4.5%	10.2%	0.7%	1.1%	0.2%																	
CALYPSO CLASS 1													2.5%	6.0%	8.8%	17.6%	26.8%	15.4%	15.4%	7.4%																			
VOLUME* (7 KG TRAYS 000S)	1	2	6	10	14	13	24	29	59	101	124	142	221	405	395	477	502	206	232	87	19	4	2	2															

KUNUNURRA (168 thousand trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1													0.1%	0.2%	7.5%	20.3%	7.1%	13.3%	17.6%	21.6%	5.8%	2.8%	2.8%	0.8%														
R2E2 CLASS 1													0.0%	0.0%	0.0%	16.4%	8.7%	30.7%	33.7%	4.2%	2.0%	1.8%	1.8%	0.7%														
HG CLASS 1																								25%	75%													
VOLUME* (7 KG TRAYS 000S)													0	0	8	28	14	31	38	33	7	3	3	2	1													

KATHERINE (1.5 million trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1														0.4%	3.5%	7.4%	10.4%	21.0%	27.8%	21.9%	4.3%	2.6%	0.6%															
R2E2 CLASS 1																	11.4%	10.3%	31.1%	19.0%	17.5%	6.4%	2.3%	2.0%														
CALYPSO CLASS 1																		4.5%	4.5%	7.1%	26.2%	22.2%	29.4%	6.0%														
HG CLASS 1																					4.5%	43.6%	43.6%	8.2%														
VOLUME* (7 KG TRAYS 000S)														2	22	46	88	183	291	260	207	190	181	44	6	4												

BOWEN/BURDEKIN (1.7 million trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1																			0.3%	4.9%	6.2%	16.5%	23.1%	23.7%	**12.2%**	7.8%	3.5%	1.8%										
R2E2 CLASS 1																0.6%	2.3%	3.3%	9.6%	8.6%	13.6%	19.9%	13%	11.5%	**11.9%**	5%	0.7%										
HG CLASS 1																								21.7%	**9.7%**	25.9%	21.6%	15.3%	5.8%								
VOLUME* (7 KG TRAYS 000S)																4	16	24	70	103	157	263	284	303	226	143	59	35	8								

MAREEBA/DIMBULAH (1.6 million trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1																							0.5%	3.2%	17.1%	27.9%	23.3%	20.5%	6.1%	1.5%								
R2E2 CLASS 1																								3.4%	16.4%	16.8%	21.2%	25.9%	12.7%	3.7%								
CALYPSO CLASS 1																									2.9%	5.8%	31.0%	38.8%	21.5%									
HG CLASS 1																											3.1%	19.5%	20.8%	37.6%	16.9%	2.1%						
KEITT CLASS 1																												0.2%	8.3%		18.7%	33.9%	17.2%	12.5%	6.9%	2.4%		
OTHER CLASS 1																													18.8%		27.8%	23.5%	1.3%	1.3%		11.9%	15.4%	
VOLUME* (7 KG TRAYS 000S)																							3	27	157	240	287	328	183	93	93	101	39	27	16	14	18	

SEQ (686 thousand trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1																							1.2%	3.1%	7.4%	7.0%	13.2%	16.8%	28.5%	12.4%	4.2%	6.2%						
R2E2 CLASS 1																							4.6%	12.5%	14.1%	11.9%	15.4%	13.8%	14.2%	9.8%	3.6%							
CALYPSO CLASS 1																												12.6%	25.6%	29.3%	18.6%	14.0%						
HG CLASS 1																										11.2%	13.4%	14.0%	5.3%	23.5%	18.8%	8.5%	3.7%						
KEITT CLASS 1																														10.2%	16.7%	34.5%	15.8%	5.3%	3.1%	3.8%	7.1%	3.3%
VOLUME* (7 KG TRAYS 000S)																							3	9	15	39	54	96	131	150	100	74	11	1	0	1	1	1

CARNARVON (87 thousand trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1																								13.5%	15.5%	18.6%	20.7%	19.2%	11.9%	0.6%								
R2E2 CLASS 1																							4.4%	7.4%	7.4%	7.4%	12.6%	22.1%	21.0%	17.7%								
HG CLASS 1																														20.9%	31.4%	18.9%	28.8%					
VOLUME* (7 KG TRAYS 000S)																							2	5	5	5	8	11	12	11	10	8	10					

GINGIN (23 thousand trays)

WEEK ENDING (FRIDAY)	5 JUL	12 JUL	19 JUL	26 JUL	2 AUG	9 AUG	16 AUG	23 AUG	30 AUG	6 SEP	13 SEP	20 SEP	27 SEP	4 OCT	11 OCT	18 OCT	25 OCT	1 NOV	8 NOV	15 NOV	22 NOV	29 NOV	6 DEC	13 DEC	20 DEC	27 DEC	3 JAN	10 JAN	17 JAN	24 JAN	31 JAN	7 FEB	14 FEB	21 FEB	28 FEB	6 MAR	13 MAR	20 MAR
KP CLASS 1																																0.5%	16.9%	55.1%	24.3%	3.3%	
R2E2 CLASS 1																																	100.0%				
VOLUME* (7 KG TRAYS 000S)																																<0.5	3	11	8	1	

***BLACK - Actual weekly volume of trays dispatched from the region across all varieties**
***RED - Forecast weekly volume of trays dispatched from the region across all varieties**

2020/2021 CROP FORECAST - DISPATCH TO THE MARKETS
UPDATED 23 MARCH 2021

ACTUAL TRAYS DISPATCHED TO MARKET: 20,000.

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC	18 DEC	25 DEC	01 JAN	08 JAN	15 JAN	22 JAN	29 JAN	05 FEB	12 FEB	19 FEB	26 FEB	05 MAR	12 MAR	19 MAR	TOTAL
CLASS 1 TOTAL	1	8	2	3	4	9	16	14	18	34	74	125	150	257	259	351	349	226	198	227	185	288	295	301	304	250	190	209	113	131	183	127	15	43	30	19	19	1	5028
CLASS 2 TOTAL	0	2	1	1	3	4	7	7	4	12	36	70	76	131	148	192	206	88	115	79	67	73	147	107	118	64	36	42	33	34	39	29	6	19	15	18	15	19	2063
TOTAL VOLUME* (7KG TRAYS 000'S)	**1**	**10**	**3**	**4**	**7**	**13**	**23**	**21**	**22**	**46**	**110**	**195**	**226**	**388**	**407**	**543**	**555**	**314**	**313**	**306**	**252**	**361**	**442**	**408**	**422**	**314**	**226**	**251**	**146**	**165**	**222**	**156**	**21**	**62**	**45**	**37**	**34**	**20**	**7091**

DARWIN (2.6 million)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC
KP CLASS 1 (%)	0%	0%	0%	0%	0%	1%	1%	1%	1%	2%	5%	9%	13%	19%	16%	16%	9%	3%	2%	1%	1%	0%	0%	0%
R2E2 CLASS 1 (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	8%	3%	24%	11%	12%	30%	4%	2%	2%	0%	0%	0%	0%
CALYPSO CLASS 1 (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	31%	22%	13%	11%	4%	8%	0%	0%	0%
HONEY GOLD CLASS 1 (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	38%	62%	0%	0%
OTHER** CLASS 1 (%)	0%	2%	1%	1%	1%	1%	2%	2%	4%	7%	9%	8%	11%	10%	9%	9%	4%	5%	4%	4%	3%	1%	1%	1%
CLASS 1 TOTAL	1	8	2	3	4	9	16	14	18	34	74	125	149	253	218	258	198	69	53	32	37	20	3	3
CLASS 2 TOTAL	0	2	1	1	3	4	7	7	4	12	36	70	76	131	135	175	157	27	49	23	24	9	2	0
VOLUME* (7KG TRAYS 000'S)	**1**	**10**	**3**	**4**	**7**	**13**	**23**	**21**	**22**	**46**	**110**	**195**	**225**	**384**	**353**	**433**	**355**	**96**	**102**	**55**	**61**	**29**	**5**	**3**

***Other: includes mostly green eating varieties such as Nam Dok Mai, Falan and Keow Savoy*

KUNUNURRA (36,000)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC
KP CLASS 1 (%)													4%	2%	14%	30%	8%	17%	9%	9%	4%	2%	1%	0%
HONEY GOLD CLASS 1 (%)													0%	0%	0%	24%	4%	44%	9%	13%	5%	2%	0%	0%
R2E2 CLASS 1 (%)													0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
CLASS 1 TOTAL													1	1	2	6	2	5	2	2	1	<1	0	0
CLASS 2 TOTAL													0	0	1	4	2	4	1	1	1	<1	0	0
VOLUME* (7KG TRAYS 000'S)													**1**	**1**	**3**	**10**	**4**	**9**	**3**	**3**	**2**	**<1**	**0**	**0**

KATHERINE (1.2 million)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC
KP CLASS 1 (%)														1%	11%	19%	22%	13%	13%	19%	1%	1%	0%	0%
R2E2 CLASS 1 (%)														0%	0%	19%	9%	11%	7%	36%	12%	6%	0%	0%
CALYPSO CLASS 1 (%)														0%	0%	0%	14%	16%	16%	15%	13%	21%	5%	0%
HONEY GOLD CLASS 1 (%)														0%	0%	0%	0%	0%	0%	0%	0%	30%	48%	22%
OTHER** CLASS 1 (%)														0%	0%	0%	0%	0%	25%	43%	0%	0%	19%	13%
CLASS 1 TOTAL														3	38	76	130	108	106	149	56	111	67	24
CLASS 2 TOTAL														0	12	12	44	38	54	42	21	22	62	3
VOLUME* (7KG TRAYS 000'S)														**3**	**50**	**88**	**174**	**146**	**160**	**191**	**77**	**133**	**129**	**27**

***Other: includes other PBR varieties such as Lady Jane and Lady Grace*

BOWEN/BURDEKIN (1.3 million)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC	18 DEC	25 DEC	1 JAN	8 JAN	15 JAN	22 JAN
KP CLASS 1 (%)															0%	0%	0%	0%	1%	1%	1%	19%	22%	23%	21%	12%	0%	0%	0%	0%
R2E2 CLASS 1 (%)															0%	2%	4%	9%	7%	9%	18%	13%	10%	12%	8%	8%	0%	0%	0%	0%
HONEY GOLD CLASS 1 (%)															0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	20%	9%	25%	28%	12%	3%
CLASS 1 TOTAL															1	11	19	44	37	44	89	141	136	153	143	95	25	29	13	4
CLASS 2 TOTAL															0	1	3	19	11	13	20	38	64	73	63	26	3	4	2	1
VOLUME* (7KG TRAYS 000'S)															**1**	**12**	**22**	**63**	**48**	**57**	**109**	**179**	**200**	**226**	**206**	**121**	**28**	**33**	**15**	**5**

MAREEBA/DIMBULAH (1.3 million)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC	18 DEC	25 DEC	1 JAN	8 JAN	15 JAN	22 JAN	29 JAN	05 FEB	12 FEB	19 FEB	26 FEB	05 MAR	12 MAR
KP CLASS 1 (%)																			0%	0%	1%	5%	11%	18%	17%	24%	15%	7%	1%	0%	0%	0%	0%	0%	0%	0%	0%
R2E2 CLASS 1 (%)																			0%	0%	0%	1%	1%	17%	48%	6%	6%	15%	7%	0%	0%	0%	0%	0%	0%	0%	0%
CALYPSO CLASS 1 (%)																			0%	0%	0%	0%	16%	15%	17%	15%	18%	13%	4%	0%	0%	0%	0%	0%	0%	0%	0%
HONEY GOLD CLASS 1 (%)																			0%	0%	0%	0%	0%	0%	0%	5%	26%	40%	11%	4%	13%	0%	0%	0%	0%	0%	0%
KEITT CLASS 1 (%)																			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	3%	26%	25%	8%	23%	12%	2%	0%
OTHER CLASS 1 (%) **																			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	42%	17%	1%	0%	6%	13%	15%
CLASS 1 TOTAL																			0	0	2	16	86	113	143	127	141	131	40	15	97	55	13	35	24	15	15
CLASS 2 TOTAL																			0	0	1	4	18	29	50	29	26	28	17	9	16	13	6	14	6	9	1
VOLUME* (7KG TRAYS 000'S)																			**0**	**0**	**3**	**20**	**104**	**142**	**193**	156	**167**	**159**	**57**	**24**	**113**	**68**	**19**	**49**	**30**	**24**	**16**

***Other: includes other varieties such as Brooks, Kent, Pearl*

SEQ (508,000)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC	18 DEC	25 DEC	1 JAN	8 JAN	15 JAN	22 JAN	29 JAN	05 FEB	12 FEB	19 FEB	26 FEB	05 MAR	12 MAR	19 MAR
KP CLASS 1 (%)																							2%	6%	13%	10%	4%	15%	16%	20%	14%	0%	0%	0%	0%	0%	0%	0%
R2E2 CLASS 1 (%)																							5%	5%	9%	17%	18%	23%	7%	12%	4%	0%	0%	0%	0%	0%	0%	0%
CALYSPO CLASS 1 (%)																							0%	0%	0%	0%	0%	2%	14%	31%	25%	29%	0%	0%	0%	0%	0%	0%
HONEY GOLD CLASS 1 (%)																							0%	0%	1%	7%	7%	15%	10%	26%	19%	15%	0%	0%	0%	0%	0%	0%
KEITT CLASS 1 (%)																							0%	0%	0%	0%	0%	0%	0%	0%	8%	16%	14%	34%	23%	3%	1%	1%
OTHER** CLASS 1 (%)																							0%	13%	0%	16%	22%	0%	49%	0%	0%	0%	0%	0%	0%	0%	0%	0%
CLASS 1 TOTAL																							3	5	12	22	19	41	51	106	82	71	2	4	3	1	<1	<1
CLASS 2 TOTAL																							1	0	1	4	4	6	10	21	22	14	0	1	1	1	<1	<1
VOLUME* (7KG TRAYS 000'S)																							**4**	**5**	**13**	26	**23**	**47**	**61**	**127**	**104**	**85**	**2**	**5**	**4**	**2**	**<1**	**0**

***Other: includes other varieties such as Nam Dok Mai*

CARNARVON (76,000)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC	18 DEC	25 DEC	1 JAN	8 JAN	15 JAN	22 JAN	29 JAN	05 FEB
KP CLASS 1 (%)																								9%	30%	34%	13%	9%	3%	2%	0%	0%
R2E2 CLASS 1 (%)																								10%	10%	11%	15%	23%	31%	0%	0%	0%
HONEY GOLD CLASS 1 (%)																								0%	0%	0%	0%	14%	13%	39%	28%	6%
OTHER** CLASS 1 (%)																								0%	4%	2%	2%	1%	0%	31%	31%	29%
CLASS 1 TOTAL																								3	6	6	5	8	9	6	4	1
CLASS 2 TOTAL																								2	4	5	3	4	4	3	1	2
VOLUME* (7KG TRAYS 000'S)																								**5**	**10**	**11**	**8**	**12**	**13**	**9**	**5**	**3**

***Other: includes other varieties such as Heidi, Valencia Pride, Nam Dok Mai, Kent, Falan, Apple*

GINGIN (68,000)

WEEK ENDING (FRIDAY)	3 JUL	10 JUL	17 JUL	24 JUL	31 JUL	7 AUG	14 AUG	21 AUG	28 AUG	4 SEP	11 SEP	18 SEP	25 SEP	02 OCT	09 OCT	16 OCT	23 OCT	30 OCT	06 NOV	13 NOV	20 NOV	27 NOV	04 DEC	11 DEC	18 DEC	25 DEC	1 JAN	8 JAN	15 JAN	22 JAN	29 JAN	05 FEB	12 FEB	19 FEB	26 FEB	05 MAR	12 MAR	19 MAR
KP CLASS 1 (%)																																	17%	16%	29%	31%	7%
R2E2 CLASS 1 (%)																																	67%	33%	0%	0%	0%
CLASS 1 TOTAL																																	4	3	3	4	1
CLASS 2 TOTAL																																	4	8	8	14	19
VOLUME* (7KG TRAYS 000'S)																																	**8**	**11**	**11**	**18**	**20**

** BLACK - Actual weekly volume of trays dispatched from the region across all varieties* ** RED -Forecast weekly volume of trays dispatched from the region across all varieties*

2021/2022 FORECAST — DISPATCH TO THE MARKETS
UPDATED 8 MARCH 2022

ACTUAL TRAYS DISPATCHED TO MARKET: 23,000

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	7 JAN	14 JAN	21 JAN	28 JAN	4 FEB	11 FEB	18 FEB	25 FEB	4 MAR	11 MAR	18 MAR	25 MAR	1 APR	TOTAL
CLASS 1 TOTAL	11	10	7	10	26	21	30	37	54	112	186	191	247	329	394	396	274	290	320	321	471	404	284	259	182	127	166	148	122	146	82	65	37	11	18	6	5	1	1	5801
CLASS 2 TOTAL	10	9	7	8	11	10	16	18	26	46	73	89	108	128	134	151	124	108	123	121	157	129	95	68	39	32	48	63	33	65	51	26	21	14	5	2	3	2	2	2175
TOTAL VOLUME* (7 KG TRAYS 000S)	21	19	14	18	37	31	46	55	80	158	259	280	355	457	528	547	398	398	443	442	628	533	379	327	221	159	214	211	155	211	133	91	58	25	23	8	8	3	3	7976

DARWIN (2.4 million)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	TOTAL
KP CLASS 1	1%	1%	1%	1%	2%	2%	3%	3%	4%	5%	11%	11%	14%	18%	14%	8%	2%	1%	0%	0%	100%
R2E2 CLASS 1	0%	0%	0%	0%	1%	1%	2%	1%	2%	6%	6%	12%	12%	17%	10%	26%	3%	0%	0%	0%	100%
CALYPSO CLASS 1	0%	0%	0%	0%	0%	0%	0%	0%	1%	10%	15%	13%	17%	13%	13%	12%	5%	1%	0%	0%	100%
HONEY GOLD CLASS 1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%
OTHER** CLASS 1	1%	1%	1%	1%	2%	2%	2%	3%	4%	12%	15%	12%	11%	9%	8%	8%	7%	1%	1%	0%	100%
CLASS 1 TOTAL	11	10	7	10	26	21	30	37	54	111	186	190	224	259	208	185	52	10	16	1	1648
CLASS 2 TOTAL	10	9	7	8	11	10	16	18	26	46	73	88	106	114	97	97	32	3	4	0	775
VOLUME* (7 KG TRAYS 000S)	21	19	14	18	37	31	46	55	80	157	259	278	330	373	305	282	84	13	20	1	2,423

**Other: includes mostly green eating varieties such as Nam Dok Mai, Falan and Keow Savoy.

KUNUNURRA (176 thousand)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	TOTAL
KP CLASS 1										1%	1%	2%	4%	3%	4%	19%	20%	19%	13%	15%	0%	100%
R2E2 CLASS 1										0%	0%	0%	1%	0%	1%	19%	22%	25%	14%	19%	0%	100%
OTHER** CLASS 1										0%	0%	31%	15%	20%	29%	0%	5%	0%	0%	0%	0%	100%
CLASS 1 TOTAL										1	0	1	2	2	3	24	27	29	17	22	0	128
CLASS 2 TOTAL										0	0	1	1	1	1	10	12	13	8	1	0	48
VOLUME* (7 KG TRAYS 000S)										1	<1	2	3	3	4	34	39	42	25	23	0	176

**Other: includes mostly green eating varieties such as Nam Dok Mai, Falan and Keow Savoy.

KATHERINE (2 million)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	TOTAL
KP CLASS 1													5%	9%	24%	22%	16%	15%	7%	1%	1%	0%	0%	0%	0%	0%	100%
R2E2 CLASS 1													0%	2%	14%	13%	10%	15%	16%	18%	10%	2%	0%	0%	0%	0%	100%
CALYPSO CLASS 1													0%	4%	8%	9%	11%	13%	16%	17%	17%	5%	0%	0%	0%	0%	100%
HONEY GOLD CLASS 1													0%	0%	0%	0%	0%	0%	4%	4%	13%	31%	14%	18%	15%	1%	100%
OTHER** CLASS 1													0%	0%	0%	0%	4%	6%	10%	9%	0%	12%	28%	20%	10%	0%	100%
CLASS 1 TOTAL													21	67	177	178	162	181	179	162	165	113	42	46	37	2	1,532
CLASS 2 TOTAL													1	13	35	43	71	75	82	68	60	33	10	8	5	1	505
VOLUME* (7 KG TRAYS 000S)													22	80	212	221	233	256	261	230	225	146	52	54	42	3	2,037

**Other: includes mostly PBR varieties such as Lady Jane and Lady Grace.

BOWEN/BURDEKIN (1.1 million)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	7 JAN	14 JAN	21 JAN	28 JAN	TOTAL
KP CLASS 1														0%	0%	0%	0%	6%	14%	19%	38%	9%	4%	4%	3%	2%	1%	0%	0%	0%	100%
R2E2 CLASS 1														0%	1%	2%	6%	10%	13%	13%	16%	13%	12%	8%	4%	3%	1%	0%	0%	0%	100%
HONEY GOLD CLASS 1														0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	37%	37%	13%	5%	1%	100%
CLASS 1 TOTAL														1	6	9	33	70	101	114	166	93	79	52	31	42	30	8	3	<1	838
CLASS 2 TOTAL														0	1	1	9	17	27	47	69	36	45	16	2	9	7	4	2	<1	293
VOLUME* (7 KG TRAYS 000S)														1	7	10	42	87	128	161	235	129	124	68	33	51	37	12	5	1	1,131

MAREEBA/DIMBULAH (1.6 million)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	7 JAN	14 JAN	21 JAN	28 JAN	4 FEB	11 FEB	18 FEB	25 FEB	4 MAR	11 MAR	18 MAR	TOTAL
KP CLASS 1																			3%	9%	30%	17%	3%	6%	7%	7%	12%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
R2E2 CLASS 1																			0%	0%	0%	34%	30%	25%	9%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
CALYPSO CLASS 1																			0%	0%	13%	22%	22%	21%	15%	2%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
HONEY GOLD CLASS 1																			0%	0%	0%	0%	0%	0%	3%	22%	27%	27%	12%	8%	0%	0%	0%	0%	0%	0%	0%	100%
KEITT CLASS 1																			0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	13%	6%	15%	25%	27%	5%	8%	0%	0%	100%
OTHER** CLASS 1																			0%	0%	0%	0%	1%	1%	0%	1%	0%	1%	23%	27%	16%	5%	2%	5%	11%	5%	2%	100%
CLASS 1 TOTAL																			7	22	140	198	162	157	110	68	103	66	57	47	30	28	27	9	18	5	2	1,256
CLASS 2 TOTAL																			2	5	28	60	40	43	31	15	17	15	8	10	5	8	10	14	5	0	0	316
VOLUME* (7 KG TRAYS 000S)																			9	27	168	258	202	200	141	83	120	81	65	57	35	36	37	23	23	5	2	1,572

**Other: includes mostly varieties such as Brooks, Kent, and Pearl.

STH QLD (505 thousand)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	7 JAN	14 JAN	21 JAN	28 JAN	4 FEB	11 FEB	18 FEB	25 FEB	4 MAR	11 MAR	18 MAR	TOTAL
KP CLASS 1																						0%	0%	3%	2%	5%	24%	27%	0%	40%	0%	0%	0%	0%	0%	0%	0%	100%
R2E2 CLASS 1																						0%	3%	6%	3%	11%	26%	37%	0%	14%	0%	0%	0%	0%	0%	0%	0%	100%
CALYPSO CLASS 1																						0%	0%	0%	0%	0%	0%	14%	29%	34%	14%	9%	0%	0%	0%	0%	0%	100%
HONEY GOLD CLASS 1																						0%	0%	0%	0%	5%	10%	20%	12%	20%	16%	13%	5%	0%	0%	0%	0%	100%
KEITT CLASS 1																						0%	0%	0%	0%	0%	0%	0%	0%	12%	21%	24%	23%	7%	0%	0%	12%	100%
OTHER** CLASS 1																						0%	0%	1%	0%	80%	0%	0%	19%	0%	0%	0%	0%	0%	0%	0%	0%	100%
CLASS 1 TOTAL																						0	1	2	1	10	23	57	52	88	41	29	8	1	0	0	2	315
CLASS 2 TOTAL																						0	0	0	0	5	19	36	19	49	40	13	8	0	0	0	1	190
VOLUME* (7 KG TRAYS 000S)																						0	1	2	1	15	42	93	71	137	81	42	16	1	0	0	3	505

**Other: includes mostly varieties such as Brooks and Nam Dok Mai.

CARNARVON (119 thousand)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	7 JAN	14 JAN	21 JAN	28 JAN	4 FEB	11 FEB	18 FEB	TOTAL
KP CLASS 1																								0%	2%	8%	34%	32%	21%	3%	0%	0%	0%	100%
R2E2 CLASS 1																								7%	10%	13%	19%	33%	18%	0%	0%	0%	0%	100%
HONEY GOLD CLASS 1																								0%	0%	0%	0%	7%	4%	28%	30%	26%	5%	100%
OTHER** CLASS 1																								0%	0%	0%	0%	0%	18%	32%	51%	0%	0%	100%
CLASS 1 TOTAL																								2	3	5	10	17	10	10	11	8	2	78
CLASS 2 TOTAL																								1	1	2	5	8	4	6	6	5	3	41
VOLUME* (7 KG TRAYS 000S)																								3	4	7	15	25	14	16	17	13	5	119

**Other: includes mostly varieties such as Heidi, Valencia Pride, Nam Dok Mai, and Kent.

GINGIN (14 thousand)

WEEK ENDING (FRIDAY)	9 JUL	16 JUL	23 JUL	30 JUL	6 AUG	13 AUG	20 AUG	27 AUG	3 SEP	10 SEP	17 SEP	24 SEP	1 OCT	8 OCT	15 OCT	22 OCT	29 OCT	5 NOV	12 NOV	19 NOV	26 NOV	3 DEC	10 DEC	17 DEC	24 DEC	31 DEC	7 JAN	14 JAN	21 JAN	28 JAN	4 FEB	11 FEB	18 FEB	25 FEB	4 MAR	11 MAR	18 MAR	25 MAR	1 APR	TOTAL
KP CLASS 1																													0%	0%	0%	0%	0%	0%	14%	29%	29%	29%	100%
R2E2 CLASS 1																													0%	0%	0%	0%	0%	0%	96%	4%	0%	0%	100%
OTHER** CLASS 1																													7%	45%	39%	0%	8%	0%	0%	0%	0%	0%	100%
CLASS 1 TOTAL																													<1	1	1	0	<1	0	1	1	1	1	6
CLASS 2 TOTAL																													<1	0	0	0	<1	0	2	2	2	2	8
VOLUME* (7 KG TRAYS 000S)																													<1	1	1	0	<1	0	3	3	3	3	14

**Other: includes green eating varieties.

* BLACK - Actual weekly volume of trays dispatched from the region across all varieties * RED - Forecast weekly volume of trays dispatched from the region across all varieties


Total Trays (000s)
700
600
500
400
300
200
100
0
09-Jul-21
16-Jul-21
23-Jul-21
30-Jul-21
06-Aug-21
13-Aug-21
20-Aug-21
27-Aug-21
03-Sep-21
10-Sep-21
17-Sep-21
24-Sep-21
01-Oct-21
08-Oct-21
15-Oct-21
22-Oct-21
29-Oct-21
05-Nov-21
12-Nov-21
19-Nov-21
26-Nov-21
03-Dec-21
10-Dec-21
17-Dec-21
24-Dec-21
31-Dec-21
07-Jan-22
14-Jan-22
21-Jan-22
28-Jan-22
04-Feb-22
11-Feb-22
18-Feb-22
25-Feb-22
04-Mar-22
11-Mar-22
18-Mar-22
25-Mar-22
Class 1 Total
Class 2 Total
20/21 Actuals

Appendix 12 - List of best management practice resources 2018/2022

Resources are included below the table.

Resource topic	Resource name	Author	Date
Temperature management	Supply chain site map revamp	QDAF	Mar-21
Irrigation	DRAFT - Irrigation	NTDITT	Jan-22
Irrigation	DRAFT - Mango Irrigation Calculator	NTDITT	Jan-22
Nutrition	Understanding crop nutrition manual which includes updated information on: - Boron - Calcium - Fertiliser application methods - Leaf and soil analysis - Mulch and Organic Matter - Nitrogen - Potassium This resource was viewed 823 times. This manual is currently being translated in Vietnamese.	QDAF	Apr-20
Orchard Management	Shoot and Flower Management – not yet uploaded on the website	NTDITT	Apr-20
Orchard Management	NT Flowering fact sheet – not yet uploaded on the website	NTDITT	Apr-20
Orchard Management	QLD Flowering Fact Sheet – not yet uploaded on the website	NTDITT	Apr-20
Orchard Management	WA Flowering Fact Sheet – not yet uploaded on the website	NTDITT	Apr-20
Orchard Management	DRAFT - Choosing tree spacing	QDAF	Feb-22
Orchard Management	DRAFT - Economics of high-density orchards	QDAF	Feb-22
Orchard Management	DRAFT - High density slim hedge designs	QDAF	Feb-22
Orchard Management	DRAFT - Making the change to high density	QDAF	Feb-22
Orchard Management	DRAFT - Plant growth regulators	QDAF	Feb-22
Orchard Management	DRAFT - Pruning mature trees	QDAF	Feb-22
Orchard Management	DRAFT - Pruning young trees	QDAF	Feb-22
Orchard Management	DRAFT - Trellis design and construction	QDAF	Feb-22
Orchard Management	DRAFT - Trellis pruning young trees	QDAF	Feb-22
Orchard Management	DRAFT - Trellis vs hedge design	QDAF	Feb-22
Pests & Diseases	DRAFT - Resin Canal Discolouration	NTDITT	Feb-22
Forecasting	DRAFT - Mango harvest timing	NTDITT	Feb-22
Export	Orchard Surveillance Timeline	AMIA	Jun-19
Export	A step-by-step guide to completing your annual online export registration	AMIA	May-18
COVID-19	COVID-19 GROWER GUIDE Also available in Vietnamese here	AMIA	Jul-19

AMIA Best Practice Resource website – Temperature Management

Suggested structure

Supply chain

- Temperature management
    - Choosing the right monitoring technology for your supply chain
    - Setting up the loggers
    - Case studies
    - Making use of the data

Temperature management content

Choosing the right monitoring technology for your supply chain

a) Videos
   - Loggers: Monitoring temperature for export, https://www.youtube.com/watch?v=MotbufPwvj8

b) Factsheets
   - Air or probe monitoring, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/9d65e29d-081a-4995-997b-c3b01723d41f
   - IoT technology, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/9be2b302-5f26-43c2-ae5f-cf724f61ae29

c) Articles
   - Temperature monitoring technology, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/a78afbff-da1c-425e-ae99-0544edf85b0c
   - Air or probe loggers?, https://www.freshplaza.com/article/9203875/should-you-use-air-or-probe-temperature-loggers/
   - Monitoring the temperatures, https://www.industry.mangoes.net.au/resource-collection/2018/4/3/monitoring-the-temperatures-of-your-fruitwhat-system-to-use

Setting up the loggers

a) Videos

b) Factsheets
   - Logger placement, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/54c3c53b-6462-40b1-b057-b44200c4d675
   - Storage temperatures, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/df0df8ce-f668-4ecf-a4f0-d1b3f4a4ea20

c) Articles

Case studies

a) Videos
   - Why monitor temperature, https://youtu.be/NautFP5oJVs
   - Temperature monitoring myths, https://youtu.be/gm7WqUPZFB4
   - Montague Fresh case study, https://youtu.be/6ZSnb1pMpSU
   - AND Fresh case study, https://youtu.be/sSN-_fFtiQI
   - Parr case study, https://youtu.be/LYQfEbCw7FQ
   - Monitoring temperature for export https://www.youtube.com/watch?v=tIHbmJS2CeQ

b) Factsheets
   - Mango case study, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/8bd4e2fe-6ac3-44b7-a2be-5463fffd624c
   -

c) Articles
   - SIM loggers case study, https://www.freshplaza.com/article/9221784/mango-exporters-embrace-real-time-shipment-monitoring/
   - RFID monitoring case study, https://www.freshplaza.com/article/9234904/au-rfid-monitoring-is-suited-to-regular-routes/

- USB loggers case study, (article available direct from DAF)*
- Shedding some light, https://www.industry.mangoes.net.au/resource-collection/2018/10/4/shedding-some-light-on-mango-supply-chains-into-asia
- Case for monitoring, Hort Connections 2018 presentation available upon request*
- Monitoring improves out-turns, Australian Citrus News Spring 2018 P25 available upon request*
- Tracking online sales, https://www.industry.mangoes.net.au/resource-collection/2019/1/8/selling-australian-mangoes-to-china-directly-through-e-commerce
- Making good decisions, https://www.industry.mangoes.net.au/resource-collection/2019/1/8/making-good-decisions-from-your-cold-chain-temperature-data
- Opening the cold chain black box, https://www.industry.mangoes.net.au/resource-collection/rcd2019-zgdky-7zkpl-s4ds8-w9rxd-l2tyb-ltxn4-2yr6m?rq=developing%20export

Making use of the data

a) Videos
   - Why re-graph temperature data, https://youtu.be/ScpHo3yVhjk
   - How to re-graph temperature data, https://youtu.be/dX1bxWHIyQQ
   - Using real time data loggers and dashboards https://www.youtube.com/watch?v=vUIhXV9vgAY

b) Factsheets
   - Rules of thumb for domestic supply chains, https://www.publications.qld.gov.au/dataset/domestic-mango-supply-chains-rules-of-thumb
   - Rules of thumb for export supply chains, https://www.publications.qld.gov.au/dataset/export-mango-supply-chains-rules-of-thumb
   - Regraphing data, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/f96611ee-6b87-4ef1-85ed-17b17d352d8b
   - Data regraphing using an Excel template, (Available upon request)*
   - Data hosting, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/8fca2012-dab0-47a0-8c47-eaa1536b12e3
   - Decision aid tools, http://www.hin.com.au/current-initiatives/serviced-supply-chain/decision-aid-tools
   - Fruit firmness, https://www.publications.qld.gov.au/dataset/temperature-monitoring-technologies/resource/1e0c455c-caf3-43dc-b34a-7a38c39f251f

c) Articles
   - Temperature management risks, https://www.industry.mangoes.net.au/resource-collection/2018/4/3/temperature-management-risks-during-sea-freight-export-of-mangoes-to-asia
   - Identifying Critical Control Points, https://www.industry.mangoes.net.au/resource-collection/2018/7/3/monitoring-triggers-practice-change

* Available on a standalone page – www.industry.mangoes.net.au/resources/resources-library/supply-chain-temperature-management-other-resources.

NOTE – OTHER ALREADY UPLOADED IN SUPPLY CHAIN AND SUPPLY CHAIN TEMPERATURE MANAGEMENT CATEGORIES–

Supply chain

- **Supply chain intro page**
- Video
    - Australian mango industry association (amia) gs1 databar webinar
    - Mango quality training for supply chain members

Supply chain -> temperature management

- Articles
    - Temperature management throughout the supply chain—how is industry tracking?
    - Using data to define best practice in the supply chain
- Poster
    - Mango handling temperature guide

Best Practice Irrigation Management for Mango Orchards

Overview

Water stress is a complicated topic in an irrigated crop. Generally speaking, a lack of rainfall can trigger agricultural drought situations, as can poor irrigation management, high temperatures and/or low humidity creating increased plant water demand.

Mangoes can be grown in a variety of climates and are adaptable to different patterns of seasonality. The timing of key processes is determined by the climate, so understanding these regionally specific differences is key to production management. Mangoes are grown in tropical, arid, desert and temperate climates across Australia.

Table 1. Types of climates where mangoes are grown in Australia and the corresponding irrigation requirements.

Climate region	Irrigation requirements
Wet/dry tropics	Does not usually require irrigation during the wet summer season. Rainfall during this time is usually sufficient to allow tree growth and fertiliser uptake after the harvest period. Will require irrigation in the dry season to enable bud growth for flowering and subsequent fruit development.
Temperate	May require irrigation all year round, although should be managed depending upon rainfall.
Arid/Desert	Requires irrigation all year round.

This project 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.

These resources have been created under the strategic levy investment project Building Best Management Practice Capacity for the Australian Mango Industry (MG17000), part of the Hort Innovation Mango Fund.

Some reference terms or critical factors that influence plant water stress and irrigation include:

- Soil (soil type, water holding capacity, soil chemistry)
- Water availability (rainfall, groundwater licensing)
- Water quality
- Environment (solar radiation, temperature, humidity, rainfall)
- Plant status (plant health, root health, nutrition, age, canopy structure, stage of growth)
- Orchard design (slope, variety, irrigation design, water monitoring equipment)

Best practices for effective irrigation

- Efficient crop water use and high yield potentials can only be achieved if the agronomic factors such as nutrition, disease and pest management are also optimised.
- Understand how water stress can affect your plants
- Understand your soil water holding capacity
- Understand your water quality and how that will affect your soil and irrigation infrastructure
- Understand how much water your crop needs through crop coefficients (irrigating based on evaporation)
- Calculate your irrigation requirements
- Ensure your irrigation system design suits your needs and has the capacity to meet the seasonal and peak water requirements.
- Reduce the need for troubleshooting through regular maintenance etc.
- A monitoring program should be used to schedule both the timing of irrigations and the volume of water to be applied.
- The movement of irrigation water in the soil profile should be monitored to ensure deep drainage is minimised.

Plant-water relationship and the effects of water stress

Irrigation is critical to the success of mango production in Australia. Since mangoes are grown in a variety of different climates, irrigation best practice differs across Australia and designing appropriate irrigation systems in any given region requires an understanding of the relationship between water and mango trees.

Mangoes are considered to be drought-hardy plants, sustained by as little as 635mm of rain per year if the rainfall is evenly spread across the year. They have adapted to drought through a number of strategies including a deep root system and “desiccation-tolerant” surface feeder roots. Where the distribution of rainfall or irrigation is uneven, water deficits can occur, which can negatively impact fruit production and the growth of young trees.

Mango trees have both shallow feeder roots and deep taproots. The feeder roots occupy the soil surface primarily in the top 10-30cm, but they can run as deep as 80cm and to a radius of around 3m from the tree. In comparison, the taproots grow up to 6m down into the soil profile.

Irrigation of mango plants targets the feeder roots, with most of the water and nutrient uptake occurring in these roots except during drought conditions when the taproot acts as the main feeder source. Nutrient uptake requires live, healthy roots. In general, the shallow feeder roots associated with nutrient uptake grow best in the soil profile which is the most favourable; moist soil will have more root growth than hard, dry soil that is not fertilised.

Figure 1: The movement of water through the plant begins at the roots, travels through the plant and out through stomata in the leaves.

Water is absorbed into the plant via the roots and moves up through the plant and out the leaves based on a water potential gradient from low to high. This gradient can increase or decrease based on environmental conditions or demand from the tree. Periods of low humidity or high temperatures can increase the gradient. Cloudy, wet conditions will reduce the gradient, and when the stomata are closed there is no water loss through the leaves. The uptake of water through tree roots can also be impacted by soil type and root health.

In mangoes, water availability can impact fruit weight, number, and quality, as well as leaf and root growth.

Table 2. The effects of water stress on mangoes depends on the timing, and extent of water deficiency.

Stage	Effect
Vegetative growth	Water stress during this stage can reduce vegetative growth.
Pre-flowering	Before flowering, **mild** water stress may promote flower induction in some mango varieties and regions. Reducing irrigation pre-flowering is a common practice in the Northern Territory used to increase flower induction. (Read the research on mild pre-flowering stress)
Pre-flowering and flowering	If not managed correctly, greater levels of water stress prior to and during flowering can cause a decline in fruit set and retention.
Fruit development	During fruit development, water stress can cause a reduction in fruit weight. Manipulating dry matter through water stress can impact fruit size and subsequently market prices.
General	In general, plant stress promotes pests and diseases in the orchard.

Read more

- Watering for mild deficits during flowering.

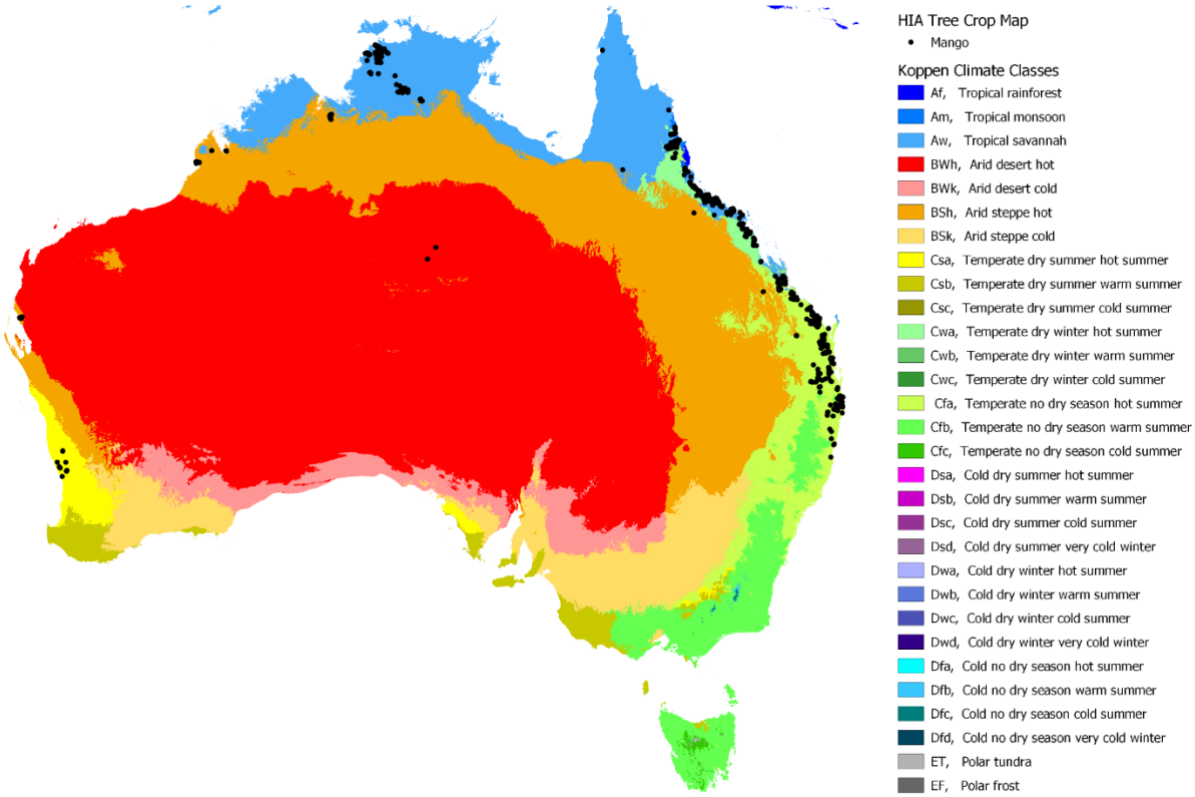


Figure 2. Location of mango orchards in Australia with climate regions. Mapping source: HIA Tree Crop Map, State of Queensland 2017; Beck, et al. 2018.

Soil water holding capacity

Water holding capacity is the total amount of water that your soil can hold. There are a couple of reference terms to describe how much water your soil is holding:

- **Field capacity** is when the soil contains as much water as it can hold.
- **Wilting point** is when the plant can no longer access water from the soil
- **Plant available water** is the difference between field capacity and wilting point.

Plant available water = Field capacity minus Wilting point

Water holding capacity and plant available water varies across soil types and are important in determining the volume of irrigation required for a crop.

Read more

Calculating your readily available water on the WA DPIRD webpage.

Water quality

The quality of irrigation water can influence plant growth, the structure and condition of the soil and the effectiveness of water application through irrigation. For instance, bore water from a shale or quartz-based aquifer can have a low pH, which can lead to nutrient leaching and nutrient deficiencies. Bore water from a dolomite or limestone aquifer can have a high pH, plus high calcium or magnesium content which can clog up irrigation lines and sprinkler heads and reduce the water flow to your crop.

Water quality tests can help to identify any issues and allow the grower to manage their irrigation more effectively. Growers must match their nutrition to their water quality parameters, soil and leaf nutrient testing will provide appropriate recommendations for both water types.

Water sampling and tests

A general physical and chemical analysis of water quality generally requires:

- 1L of water is sampled in a bottle with no air gap,
- Stored <6°C and
- Supplied to a laboratory within 48 hours.

General chemical and physical test that may be relevant for mango irrigation are pH, Conductivity, Total Dissolved Solids (TDS), Sodium, Potassium, Calcium, Magnesium, Total Hardness, Total Alkalinity, Iron, Chloride, Sodium Chloride, Sulfate, Silica Nitrate and Fluoride.

Water quality parameters

Although there is little published research to define the limits to water quality parameters for mango production, a general guide for salt content, pH, alkalinity and hardness of irrigation water is provided below.

Table 3. Primary irrigation water quality parameters (Adapted from WA AGRIC, 2019. Water salinity and plant irrigation).

	Description	Suitable range
Salinity	Salts in irrigation water are mainly common salt (sodium chloride), calcium and magnesium bicarbonates, chlorides and sulphates. The salinity of water is usually estimated from its electrical conductivity (EC), which can be converted to total dissolved solids (TDS). The EC does not identify the salts present but gives a fairly reliable indication of salinity problems. EC is measured in milliSiemens per metre (mS m^{-1}).	<1000 mgL^{-1} TDS
pH	The test for pH measures the balance between positive hydrogen ions and negative hydroxyl ions. This test indicates if water is alkaline (pH >7), neutral (7) or acid (<7).	• pH 5.5 to 8.5 is suitable for most plants. • If pH <6, corrosion of metal pipes and fittings can start. • If pH <4, water can contribute to soil acidity. • If pH >8.5 or <6, spray mixes can be affected.

Alkalinity	Alkalinity is a measure of the total or hydroxyl ions. It is mainly caused by the presence of bicarbonates and carbonates in the water, and should not be confused with the measurement of pH. It is measured as mg/L $CaCO_3$ equivalent.	• <90 mgL^{-1} – low risk of problems occurring • 90–335 mgL^{-1} – moderate risk declining soil structure, reduced plant growth from prolonged use, and accumulation of a white scale on plants spray-irrigated in high humidity weather • >335 mgL^{-1} – high risk of soil problems and reduced plant growth, and a build-up of scale, which blocks metal pipes • >500 mgL^{-1} – can be harmful to human health, but water develops an unpleasant taste well before this level.
Hardness	Hardness means the concentration of all the metallic cations in water. It is a measure of the dissolved calcium and magnesium salts and is expressed as mg/L $CaCO_3$. Over time, hard water can block hot water systems, metal pipes and irrigation fittings, and can reduce soil structure.	Water with less than 100 mgL^{-1} $CaCO_3$ is generally regarded as suitable for most uses. Suggested hardness limits are: • 300 mgL^{-1}: for mixing chemical sprays and dips, and can have an adverse effect on soil structure • >500 mgL^{-1}: limit for most other uses.

Water quality issues

Read more

Physical and chemical parameters of irrigation water can impact soil health and structure. The NSW DPI have a great article on-farm water quality and treatment.

pH

Read more

The pH level of water can accrue in the soil over time, changing the soil pH, and the number of nutrients available to the plant. Read more about pH ranges and the effect on soil on the Queensland Government webpage.

Sodium

The physical structure of soil can be altered by irrigation of water with high sodium content, causing the development of sodic soil. The three main problems caused by sodium-induced dispersion are:

- reduced infiltration
- reduced hydraulic conductivity
- surface crusting

Read more

Sodic soils on the WA DPIRD webpage

Boron toxicity

Irrigation water in Carnarvon can contain moderate to high levels of boron (0.2 to 1 mgL^{-1}). Water with a boron concentration over 0.5 mgL^{-1} is considered marginal for sensitive crops such as avocados, grapes and stone fruit, but no information is available for mangoes. Irrigation water high in boron can result in the accumulation of boron in the tree's root zone. A symptom of boron toxicity in mangoes is a wavy burn pattern along the margins of older leaves starting at the leaf tip.

Read more

Boron toxicity at the WA DPIRD webpage.

Hard water

Water with high concentrations of calcium salts can calcify over time, blocking irrigation equipment including sprinkler heads, irrigation lines etc. This reduces the water flow through the system.

Read more

The NSW DPI have a great article on-farm water quality and treatment, including information on treating hard water.

Particles

The efficacy of irrigation can be altered by water quality through the deterioration of irrigation infrastructure. Water with high concentrations of particles or solids will require filtration to ensure irrigation infrastructure does not block over time.

Salinity

Read more Salinity and the effect on soil on the WA DPIRD webpage

Irrigating based on evapotranspiration

Plant water use is determined by a mixture of environmental and plant-based factors. Some important reference terms to know include:

- **Evaporation**, which is the process of water being converted into vapour.
- **Transpiration**, which is the process that generates water loss from the plant.
- **Evapotranspiration**, which is a combination of the above, the water lost from a plant due to the water gradient between the plant and the environment. This is calculated based on a mix of solar radiation, wind speed, air temperature and humidity.
- **Crop factor (CF)** is a crop-specific proportion of evaporated water that needs to be replaced by irrigation.
- **Crop coefficient (Kc)** similar to CF but refers to the proportion of evapotranspiration that needs to be replaced.

Crop factors and crop coefficients vary based on the type of crop, height, age, growth stage (flowering, fruit set etc.) and condition. For mangoes, critical stages are those that contribute directly to the success of the mango crop are the following:

1. Flowering induction
2. Full flowering
3. Fruit set and development

Table 4. Summary of crop coefficient stages

Stage	Practice	Crop coefficient
Pre flowering	Reducing irrigation prior to inductive conditions will allow shoots to mature and be ready for flowering.	0.39
Flowering and fruit set	Water stress during flowering can result in poor flower development and will limit fruit set. Start watering before flowering to initiate bud growth. Ensure the onset of bud growth is timed with cool inductive temperatures.	0.8-0.85
Fruit development	Water stress during fruit development results in increased premature fruit drop and reduced fruit size. Any water stress during the last month of fruit development can increase the risk of sunburn. To overcome this, irrigation may be needed during the hottest part of the day.	0.8-0.85
Pre-harvest and harvest	Reduced irrigation before harvest helps advance the maturity of the fruit and increase fruit dry matter content.	0.58-0.60
Post-harvest vegetative growth	Restart irrigation immediately after harvest to incorporate fertiliser and encourage a good autumn flush.	0.90

Calculating irrigation requirements

You can schedule irrigation based on the crop factor or crop coefficient broadly using the following calculation.

Daily water use (mm) = Evapotranspiration (mm) x crop coefficient

The following calculation (step 1 below) can be used to estimate your overall crop water requirements if you are applying for a water license. With a little more information it can also be used to schedule your irrigation, using the application rate of your mini-sprinklers and knowing your soil's water holding capacity (readily available water). See the following example for calculations.

Step 1: Calculate DAILY water requirements

- Evapotranspiration data from the BOM website, e.g. 6.2 (mm)
- The crop factor for mangoes at the current stage, e.g. pre-flowering 0.39
- Calculate the daily water requirement:

Daily water requirements = evapotranspiration x crop coefficient (Kc)

2.42mm = 6.2 x 0.39

Step 2: Calculate how much capacity your soil has

- Know the readily available water storage of your soil (see section above), e.g. 3mm per 100mm depth
- Calculate soil water storage by multiplying the effective root depth by the soil readily available water:

Root depth x readily available water = soil water storage

300mm root depth x 3 / 100 = 9mm

Step 3: Calculate irrigation run time per day

- Use the application rate of your mini sprinklers, e.g. 10mm per hour
- Daily water requirement calculated above, 2.42mm
- Calculate the run time in minutes:

Water required / application rate x 60 = run time

2.42 / 10 x 60 = 14.52 (round up to 15 minutes)

Result: This means that the daily water requirement is 2.42 mm (step 1), the soil has 9mm of storage capacity (step 2) so the irrigation can be applied once a day for 15 minutes (step 3).

Irrigation design

Irrigation design impacts the performance and efficiency of the system. There are professional irrigation designers who can assist with designing an appropriate system for your orchard. If you are looking for a certified irrigation specialist, Irrigation Australia administers a voluntary irrigation industry accreditation scheme. Here are some points to bear in mind when discussing your irrigation design:

- Legislative requirements for monitoring water usage etc.
- Topography (elevation can result in pressure loss)
- Block layout
- Soil type, structure, chemistry and water holding capacity
- Water quality
- Crop details (age and crop factors/coefficients)
- Irrigation type- for mangoes irrigate under the tree without wetting the foliage (e.g. under-tree mini-sprinklers or drip) to enable disease management and increase water use efficiency.

Troubleshooting and checking your irrigation system

For optimal water use efficiency, it is useful to check that the irrigation output matches what the system was designed for.

Catch test

When your irrigation is running, select at least 9 sprinkler heads from various locations (the beginning, middle and end of the line for at least 3 lines) and place each one into a bucket. Run the water for 2 minutes and measure the amount of water that is captured in the bucket and calculate the output. The measurements should be within 5% of each other for an efficient system.

Calculate your irrigation output

- Using a measuring cylinder calculate how much water has pooled in each bucket in mL, e.g. 50mL of water after 2 minutes
- 50 x 30 =1500 mL per hour
- 1500 ÷ 1000 = 1.5 L per hour.

Pressure gauge

Inline pressure gauges can be used for the water pressure in your irrigation lines. Once again, checking at different locations will provide an overview of any variation or inefficiencies in your system.

Check your irrigation

As discussed in water quality, both salts and particles can build up over time and cause problems in your pumps and lines. Monitor your water quality and if you have magnesium, calcium or particles present in high levels, pay particular attention to your pressure and fittings. Check sprinkler heads regularly to reduce blockages and if necessary, invest in a system to reduce the build-up of salts/particles.

Read more

The NSW DPI have a great article on-farm water quality and treatment, including information on treating hard water.

Water monitoring systems

Water efficiency and water monitoring technology have advanced significantly in the past decade. There are several systems that allow growers to schedule their irrigation to suit their crop's water requirements, these can be evapotranspiration based (as discussed above), soil-based (monitoring the progression of water through the soil profile), or plant-based (looking for plant stress).

Soil moisture monitoring

Soil moisture monitoring systems allow for the management of irrigation timing and volume. If irrigation exceeds the soil water holding capacity in the root zone, then the excess is wasted through leaching, removing nutrients in the process. Soil moisture probes allow irrigation scheduling to target the active root zone.

Soil moisture monitoring systems or irrigation calculators can signal when irrigation is required. Trends in soil moisture determined over time will indicate the rate at which water is taken up by the crop or lost via evaporation or drainage. These trends can then be used to schedule irrigation based on environmental conditions and crop growth stages.

Below the refill point, the soil moisture will impact plant stress and productivity. The refill point can be estimated by measuring soil water potential or by analysing daily water use patterns to determine when the crop is finding it difficult to remove water. As different soils hold varying amounts of water, the refill point will not be the same for different soils. As sandy soils hold less water, they require less water to reach field capacity and therefore the

refill point is higher (-8kPa). Clay soils hold more water and therefore the refill point may be lower (-20kPa).

To ensure plant stress doesn't occur, the refill point should include a buffer. This is important as the decline in soil moisture is usually confirmed followed by a delay in applying irrigation water. To combat this, the refill point should be halfway between field capacity and the permanent wilting point, or when half the readily available water has been lost. For example, in a clay loam soil, field capacity is approximately 375mm of water in 1m of soil with 150mm of readily available water. When the soil moisture content drops to 300mm (half of 150mm), irrigation should commence. This avoids the soil moisture content reaching 225mm or the permanent wilting point. Note that these values will vary for different crops and are a guide only.

Real-time monitoring can use thresholds for soil moisture to trigger irrigation systems. For example, a tensiometer at 30cm depth installed in a sandy soil has a critical soil moisture tension of -8 kPa. When this is achieved, it is suggested that irrigation is applied and hence this is the refill point. This is suggested for mangoes produced on the Swan Coastal Plain in Western Australia under high evaporative conditions (summer) (WA AGRIC). Similarly, soil moisture sensors and capacitance probes can measure soil moisture in mm or percent (%). Refill points or soil moisture thresholds can be established for different sites to trigger irrigation.

For best results when using soil moisture monitors:

- Ensure sensors are placed throughout the entire orchard.
- Soil moisture sensors should be placed throughout the root zone 0-15cm, 15-30cm and 30-60cm to capture drainage from the profile.
- Use trends in soil moisture to schedule monitoring.
- If salt needs to be flushed from the root zone the deeper sensors need to be registering drainage of irrigation water.

Read more

Soil moisture monitoring to fine-tune irrigation scheduling on the WA DPIRD webpage.

Plant-based irrigation management

Plant-based irrigation management is driven by plant stress, with sensors that measure an aspect of plant stress. There are several different sensors on the market, some of which require contact with the plant, and others which are contactless.

Read more

Plant-based sensors for irrigation management information in the Agriculture Victoria fact sheet.

Water resources

The control, extraction and licensing of water is variable based on your location and may be subject to change. For information on this topic, contact the state water department for your location.

Table 5. Overview of water licensing in NT, QLD and WA for extraction of water for irrigation of mango crops in 2020-21.

NT	QLD	WA
Conditional licenses required if you are in a water control district or if you don't have direct access to water.	License required for surface water. Conditional for groundwater, yes if you are in an area established through the Water Regulation 2016 or a water plan.	Conditional, water license required if you are in a proclaimed groundwater area or if the water is drawn from an artesian source.

How to manage your own access to water

For best practice, the following should be undertaken before the establishment of mango orchards:

- Orchard and irrigation design planning.
- Estimation of water requirement, including buffers for extreme weather, drought and emergencies.
- Identification of water availability, quality, security of supply and any associated costs.
- Assessment of suitability of the site based on the above in conjunction with climate records and projections.

Once the orchard is established, actively manage and monitor water access through the relative managing body and environmental monitoring agencies. Have management plans in place for drought and extreme years, and adapt plans to changing climatic conditions. Keep informed of the relevant policy and regulatory frameworks that may influence access to

water in your region. Continue to invest in improving water use efficiency and reduce the environmental impacts of irrigation.

How to measure and report how much water you need now and will need in the future

Irrigation calculations can be used to estimate the volume of water required now and in the future. Estimate the water requirement of an orchard now by using recent or long-term average climate variables.

It is important to also consider how the climate of your production region may change and how this could impact the water requirement of an orchard. Changes to rainfall and evaporation have been projected in various climate models and these can be used to estimate variation in water requirement under future emissions scenarios. This is particularly important for the establishment of new orchards that are expected to remain in production for up to 30 years.

Climate change projections can be accessed on either the Climate Change in Australia website or on the Australian Landscape Water Balance (ALWB) simulated data.

Summary

Irrigation management is a very complicated topic, influenced by soil, water availability, water quality, the environment, the plant and the orchard design. As an irrigation chapter, many of these aspects are touched on briefly, but are outside the scope of this information sheet. For more information on these topics, there is a wealth of information both through the links above as well as occasional courses offered by specialists.

There are professional irrigation designers who can assist with designing an appropriate system for your orchard. If you are looking for a certified irrigation specialist, Irrigation Australia administers a voluntary irrigation industry accreditation scheme.

Key references

Allen, R. G., Periera, L. S., Raes, D., Smirth, M. 1988. Crop evaportranspiration – Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. http://www.fao.org/3/X0490E/x0490e00.htm#Contents

Beck, H., Zimmermann, N., mcvicar, T. *Et al.* Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci Data* **5,** 180214 (2018). Https://doi.org/10.1038/sdata.2018.214

Bithell, S. L., Diczbalis, Y. And Moore, C. (2010). Review of Mango Irrigation Research in the Northern Territory. Northern Territory Government, Australia. Technical Bulletin No. 334.

Blaikie, S. And Cavanagh, P. 2003. Operation KP. Trophort. Https://dpir.nt.gov.au/__data/assets/pdf_file/0008/227825/op4_operation_kp.pdf

Carr, m. K. V. (2014). The water relations and irrigation requirements of mango (mangifera indica l.): a review. *Experimental Agriculture, 50*(1), 1-23. Doi:http://dx.doi.org/10.1017/S0014479713000288

Durán Zuazo, Víctor & Raya, A.Martínez & Ruiz, J.Aguilar. (2004). Impact of salinity on the fruit yield of mango (Mangifera indica L. Cv. 'Osteen'). European Journal of Agronomy. 21. 323-334. 10.1016/j.eja.2003.10.004.

Growcom, 2020. Https://www.growcom.com.au/_uploads/LWR/CB1_Mangoes%20TP.pdf

Https://www.hort360.com.au/wordpress/wp-content/uploads/2019/11/CB1_Mangoes-NQ-TP.pdf

Http://www.scielo.br/scielo.php?Script=sci_arttext&pid=S1415-43662014000400002

Https://www.agric.wa.gov.au/sites/gateway/files/Farmnote%20-%20Mango%20growing%20in%20Carnarvon.pdf

Http://www.wrc.org.za/wp-content/uploads/mdocs/1136-1-031.pdf

Https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/531957/determining-readily-available-water-for-im.pdf

Kirkham, M.B. 8 - Field Capacity, Wilting Point, Available Water, and the Non-Limiting Water Range, Editor(s): M.B. Kirkham, Principles of Soil and Plant Water Relations, Academic Press, 2005, Pages 101-115, ISBN 9780124097513, https://doi.org/10.1016/B978-012409751-3/50008-6.

Lu, Ping, 2005. Mango water relations and irrigation scheduling. International conference on mango and date palm: Culture and export. Malik et al. (Eds) University of Agriculture, Faisalabad. http://www.geocities.ws/mdce2005/MDCE2005/10-9_19.pdf

Lu, Ping & Chacko, E.K.. (2000). Effect of water stress on mango flowering in low latitude tropics of Northern Australia. Proceedings of the Sixth International Symposium on Mango,

Vols 1 and 2. 509. 283-289. 10.17660/ActaHortic.2000.509.31. (https://www.researchgate.net/publication/262804979_Effect_of_water_stress_on_mango_flowering_in_low_latitude_tropics_of_Northern_Australia/citation/download

Moore, G A. (2001), Soil guide (Soil guide): a handbook for understanding and managing agricultural soils. Department of Agriculture and Food, Western Australia, Perth. Bulletin 4343.
https://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?referer=http://scholar.google.com.au/&httpsredir=1&article=1001&context=bulletinsState of Queensland (Department of Science, Information Technology and Innovation), October 2017

IRRIGATION CALCULATOR (AUTOMATIC)

Enter values into the yellow boxes. Select either a location and soil type or manually enter the rainfall, evaportanspiration (ET) and soil water holding capacity (WHC).

Select a crop	Mango		
Select development phase	Flowering		
Select month	July		
Mean monthly rainfall (mm)	0.6	or location	Darwin
Mean monthly ET (mm)	39	or location	Darwin
Soil WHC (mm/m)	137.5	or soil type	sandy clay loam
Irrigated area (%)	70		
Total area (ha)	1		
Irrigation efficiency	0.85		

Effective rainfall	**#N/A**	mm
Crop water requirement	**#N/A**	mm
Water deficiency	**#N/A**	mm
Volume per ha	**#N/A**	ML/ha
Volume per area	**#N/A**	ML/area
Volume per day	**#N/A**	ML/area/day

A BEST PRACTICE RESOURCE

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1. Assumes soil depth available for root zone water uptake is 100cm; 2. Calculation aims to prevent drainage by limiting irrigation volume below soil WHC; 3. Assumes that the first 5mm of rain is not effective.

Canopy Management: Shoot/Flower Management

The management of mango tree shoot and flower growth can positively influence fruit yield. It is important to understand the natural processes that support flower development to develop appropriate management practices. Practices must also suit the unique conditions of different production regions and mango varieties.

The process of mango flowering relies on all the components of canopy growth such as bud initiation, leaf maturation and stem growth. Driving these components are abiotic or environmental factors such as water, nutrient availability, and temperature (see Figure 1) along with endogenous hormonal regulation that occurs within the plant. The key component of canopy growth that controls the emergence of flowers includes what are described as initiation and induction events.

What is flower induction?

Flower induction is the process of initiating floral shoot growth as opposed to vegetative shoot growth. This process begins with shoot initiation which can be observed as the transition of a dormant bud into active growth by swelling and can be stimulated by pruning, defoliation, changing from dry to wet conditions, fertiliser application, and change in temperature as well as other factors. This process is regulated by phytohormones thought to be auxins from leaves and cytokinins from roots which appear to govern the initiation cycle. Auxins are known to stimulate growth in roots which in turn produce cytokinins which are major factors in stimulating shoot initiation. When leaves age the amount of auxin produced diminishes resulting in higher ratios of cytokinin hormones compared to auxins. This promotes shoot initiation and proliferation whilst higher levels of auxins will inhibit shoot initiation.

Induction is the temporary commitment of buds to evoke a particular shoot type upon initiation. It is regulated by the interaction of a putative temperature-regulated florigenic promoter (FP) and an age-dependent vegetative promoter (VP) (Davenport and Núñez-Eliséa, 1997; Davenport, 2000, 2003, 2008). The FP appears to respond during exposure of leaves to cool temperatures and is down-regulated to a constant basal level when temperatures are warm (Davenport, 2000). In contrast, the VP is thought to gradually decrease within leaves or buds as stems age, impacting the fate of initiating buds up to about four months after the young flush development. The ratio of FP to VP in buds, is thought to induce formation of the distinct shoot types; i.e. high FP to VP ratio induce

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generative floral shoots, low FP to VP ratios induce formation of vegetative shoots, and intermediate FP to VP ratios may be responsible for formation of mixed shoots.

Mango varieties differ significantly in their floral behaviour. Characteristics like timing, flower sex ratio, panicle size, duration of flowering, number of flowers and other traits vary with different genotypes. As a result, varieties will perform differently under particular environmental conditions and management practices. Some varieties are better suited to hotter environmental conditions, whereas some varieties are better suited to cooler conditions. Sensitivity to high temperatures during the flowering of new and common varieties is displayed in **Error! Reference source not found.**. These types of considerations will be important to future-proof the industry to prepare for expected changing climates.

Triggers for floral induction

Environmental conditions that create floral stimuli are believed to be cooler temperatures. The exact temperature conditions required for floral induction vary across cultivars. The reported temperature regimes for achieving flowering of most mango cultivars grown in Australia is when minimum temperatures between ~12 to 20°C and maximum temperatures between ~18 to 32°C coincide. However, although flowering may occur at the lower range of temperatures (~10 / 18°C), some key areas of floral development are negatively affected by colder temperatures. Two examples of this include shoot initiation, which is slower and, in some cultivars suppressed entirely, in day/night temperature regimes below 15 / 20°C, and flower sex ratio which is less favourable in temperatures below 15°C for most cultivars.

The arrival of whether that supports the occurrence of the temperature regimes described above, dictates to onset of flowering in production regions around Australia. Flowering is usually staggered between May and October, starting in the North and ending in Southern regions (Figure 2).

The arrival of inductive conditions

In the Northern Territory and northern Western Australia, the onset of cool inductive whether occurs when a high-pressure system in southern Australia draws cool air up to the north. This can be anticipated by viewing the wind and sea level pressure forecast on the Bureau of Meteorology website. During this time, night time temperatures are below 20 but day time temperatures are routinely ~30°C. This usually occurs between May and August (Figure 5).

In Queensland, New South Wales and southern Western Australia winter conditions can be too cold for mango flowering. During these periods, mango trees growth becomes dormant. If conditions temporarily become warm enough to flower in this time, flowers that do develop can be abnormal and often don't set fruit. As conditions warm in late winter to spring in these

regions, flowering is more successful. Typically mango flowering in Queensland occurs in August and September, followed by New South Wales and southern Western Australia continuing into October.

Management practices that promote flower induction

There are a range of management practices that can enhance or promote floral induction in mango orchards. It is important to note that these practices cannot replace natural inductive conditions, rather they should be simultaneously used in targeted ways. The conditions which promote flower induction are those that prevent new vegetative growth and mature existing leaves. Examples of these conditions include water stress, flooding, cool temperatures, high evaporative demand and girdling. The following management practices imitate these conditions and can therefore be used to promote flower induction.

Water Stress

Inducing water stress can supress vegetative growth but it does not trigger shoot initiation. This process can be valuable under highly productive conditions before the onset of inductive temperatures, as it will help to age the existing and restrict new vegetative growth to prepare for flower induction. The onset of irrigation after a period of water stress initiates shoot growth which may result in flower induction if favourable environmental conditions occur. Excessive water stress during periods of no growth can cause desiccation of buds and water stress after shoot initiation can limit shoot, flower and fruit growth.

Pruning

Pruning or removal of vegetative or floral shoots early in the inductive stage, can reset the canopy to promote new growth. If timed correctly with inductive conditions, the new growth can result in the production of flowers on mature terminals. This process can be utilised to either delay or synchronise flowering.

Chemical application

Chemicals used to promote flowering can be categorised as either plant growth regulators or floral promotors. Plant growth regulators limit or remove the inhibitory effect on flowering of young vegetative leaves. Floral promoters stimulate floral initiation by promoting shoot initiation during inductive conditions. If timed correctly, these applications can improve flower production during inductive conditions.

Paclobutrazol is a plant growth regulator registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA). The postharvest application of paclobutrazol to the soil can have a significant effect on flowering and fruiting in the following year. It acts by reducing tree vigour, preventing excessive vegetative flushing in the lead up to flowering.

Applications can be made after harvest and up until mid-February. A study has found that it is most effective to apply paclobutrozol 120 days before bud break for flowering (Bhagwan, A., et al. 2013).

Potassium nitrate is a floral promoter that acts by promoting the development of buds. When timed with cool weather, the initiation of bud growth can result in increased floral induction. Studies suggest that potassium nitrate is most effective as a foliar spray applied at night.

Boron and potassium nitrate are important nutrients in the promotion and development of flowers. These should be applied according to regular leaf nutrient analysis results.

Table 1. Chemicals for use in the management of mango flowering.

Chemical	Action	Application*	Timing*	Considerations
Paclobutrazol (APVMA regulated)	Growth regulator	Collar soil drench. 8 – 20 ml per tree (dependent on tree size)	Apply 4 weeks after harvest, no later than mid-February	Do not treat trees with canopies less than 3 m in diameter
Potassium nitrate	Floral promoter	3% KNO_3 foliar spray at night	Apply in the days leading up to cool inductive temperatures	If temperatures are not cool enough for floral induction, vegetative growth will occur
Ethephon (APVMA regulated)	Growth regulator	Application rate depends upon product type. Refer to permit	Apply initial foliar spray at early vegetative to first floral bud development and repeat approximately 28 days later	Do not apply more than two spray applications per season
Boron	Floral development	Foliar spray and soil application based on leaf analysis	Apply foliar at bud break, but maintain levels with soil applications at other times.	Boron can be toxic to mangoes at high levels

*Seek expert advice and adhere to label rates.

Girdling

Trunk or branch girdling (cincturing) limits vegetative flushing, therefore, causes the last flush of leaves to age. When carried out in late summer-early autumn, this has been found to occasionally increase flowering. However, girdling causes significant stress for a tree and in extreme cases is known to cause tree death.

Resources

1. Australian Government Bureau of Meteorology (BOM). 2020. Monthly mean maximum temperature data for several locations. Retrieved from http://www.bom.gov.au/climate/data/
2. Batten, D., & McConchie, C., 1995. Floral Induction in Growing Buds of Lychee (*Litchi chinensis*) and Mango (*Mangifera indica*). Functional Plant Biology, 22(5), 783-791.
3. Clonan, M., McConchie, C., Hall, M., Hearnden, M., Oleson, T. and Sarkosh, A. 2020. Effects of ambient temperatures on floral initiation in Australian mango (Mangifera indica L.) selections. Unpublished manuscript.
4. Bhagwan, A., K. Vanajalatha, S. K. Sarkar, G. Anabheri and A. K. Misra., 2013. Standerdization of dose and time of soil application of Cultar on flowering and yield in mango cv. Banganpalli. Journal of Ecofriendly Agriculture 8, 39-43.
5. Davenport, T. L. and Nunez-Elisea, R. 1997. Reproductive physiology. In: Litz, R. E. ed. The mango— botany, production and uses. Oxon, CAB International. 69-146.
6. Davenport, T.L., 2000. Processes influencing floral initiation and bloom: the role of phytohormones in a conceptual flowering model. HortTechnology 10, 733-739.
7. Davenport, T.L., 2003. Management of flowering in three tropical and subtropical fruit tree species. HortScience 38, 1331-1335.
8. Davenport, T.L., 2008. Reproductive physiology. In: Litz RE (ed), The Mango, Botany, Production and Uses. 2nd Edition. CAB International, Wallingford Oxon. In press.
9. MG12012 - Manipulating mango flowering to extend harvest window

Tables and Figures

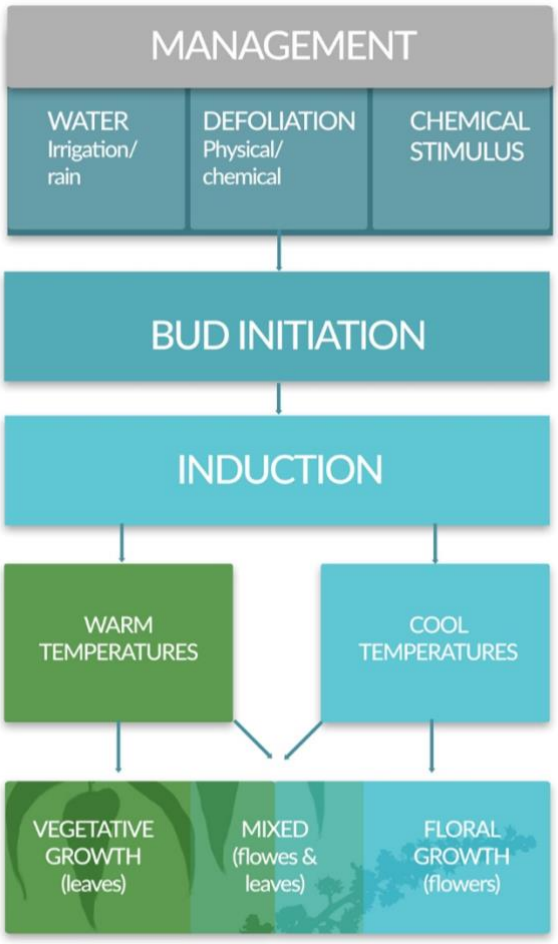

Figure 1. Mango flowering flowchart with management opportunities.

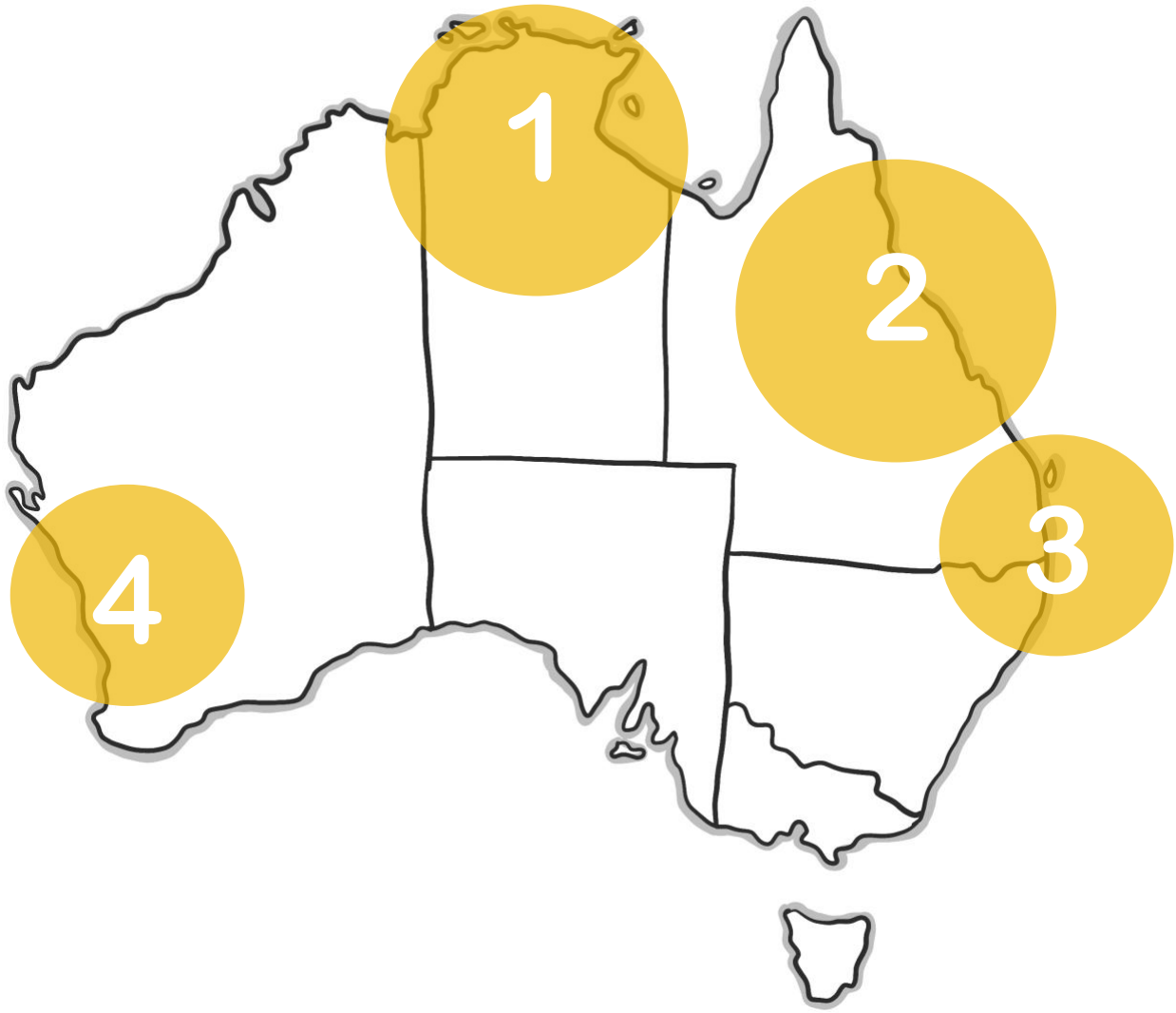

Figure 2. The occurrence of mango flowering around Australia starting in May in the Northern Territory (1) and finishing in southern Western Australia (4) in October (the highlighted regions are indicative only).

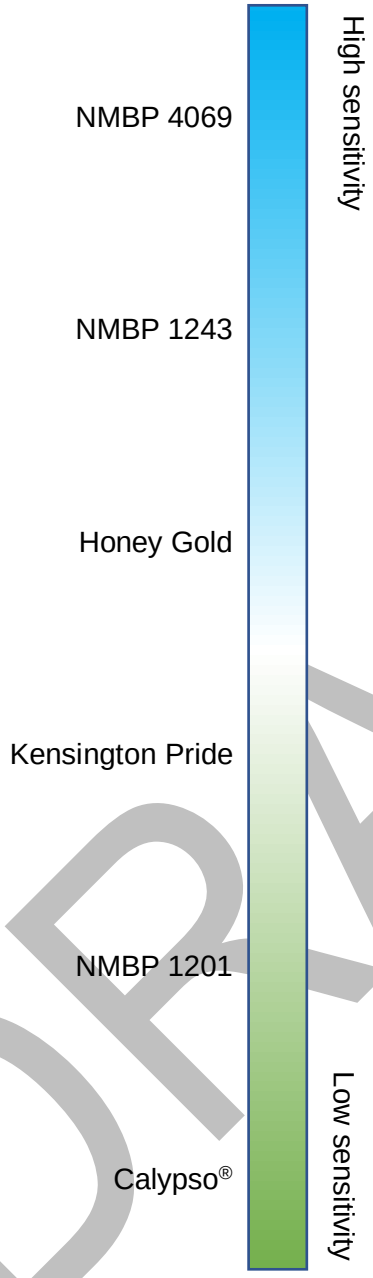

Figure 3. Cultivar sensitivity to high temperatures during flower induction in the Northern Territory (Clonan, M. et al. 2020).

Figure 4. Mango flowers

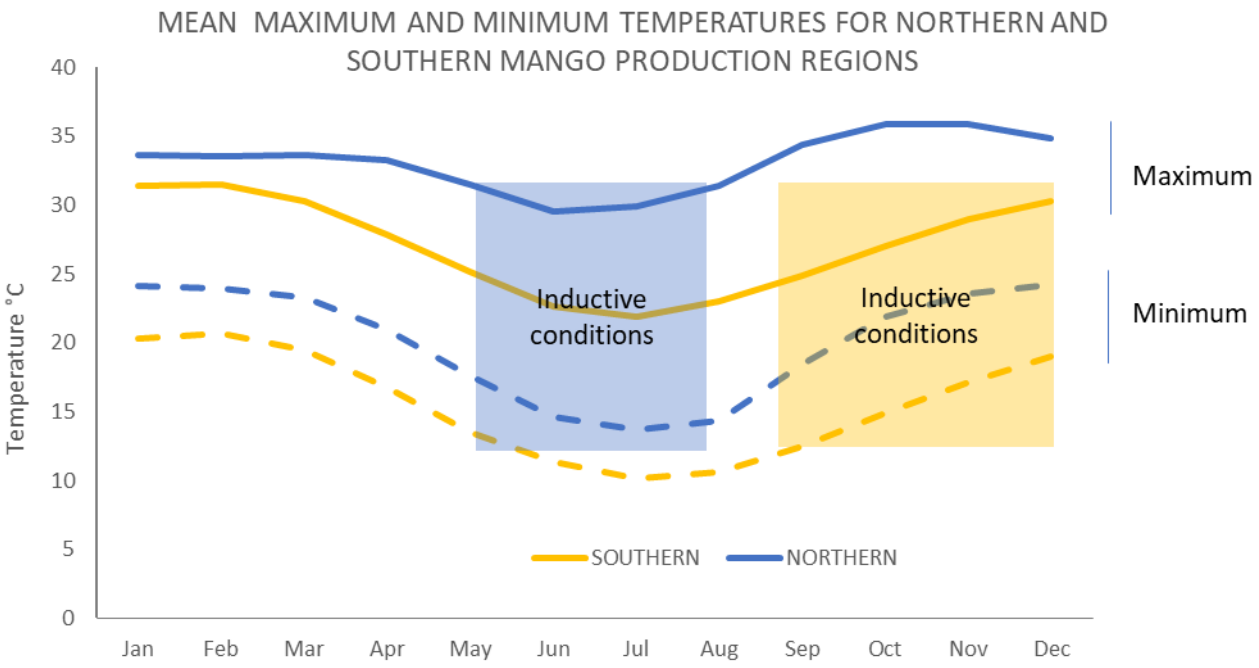

Figure 5. Difference in monthly minimum and maximum temperatures for southern and northern mango production regions.

Mango Flowering in the Northern Territory

Production regions found in the Northern Territory (NT) experience flowering between the cool season months of April and August. Harvest will usually start around July/August with the earliest flowering varieties reaching maturity first in the Darwin region. Harvest in the NT continues into December when the last fruit reaches maturity in the Katherine/Mataranka region.

Annual production cycle

The annual production cycle in this region is dictated by the arrival of cool-season weather between April and August (Figure 1). Changes to the timing of its arrival will change the timing of flowering. The fruit growth component of the production cycle also relies on temperature as too cool or too hot temperatures can limit fruit growth. Warm temperatures throughout the off-season period (December to March) coincide with monsoonal rainfall which encourages vegetative growth and tree recovery. This is a critical period in the annual cycle of the tree where carbohydrate reserves are accumulated to support future plants functions, such as flowering.

Climate drivers for flowering

The NT region is unique amongst other mango production regions in Australia as it has consistently warm maximum temperatures which ensure growth all year round. However, as occurrences of cool weather are restricted to a short period, opportunities for flower induction are limited. The onset of cool weather occurs when high pressure systems in southern Australia direct cool dry south-easterly air streams to Northern Australia. This phenomenon can be observed and forecasted in wind maps of Australia, found on the Bureau of Meteorology website. The timing of arrival of cool weather in the NT can vary from year to year.

After the commencement of the cool period, the daily maximum and minimum temperatures fluctuate slightly. This fluctuation may limit the potential for induction of mango flowers during this time, depending on the specific temperature thresholds for each mango variety.

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Management practices for the NT

Key management practices that promote mango flower induction in the NT are:

1. Preventing new vegetative growth immediately before flowering by limiting irrigation and preventing the application of nitrogen fertilisers.
2. Foliar applications of boron and potassium nitrate at bud break may increase flower number and vigour.
3. Apply paclobutrozol 4 weeks after harvest or no later than mid-February.

Key references

Australian Government Bureau of Meteorology (BOM). 2020. Monthly mean maximum temperature data for several locations. Retrieved from http://www.bom.gov.au/climate/data/

Technical Report, Chapter 7 Regional Climate of Northern Australia. East Arm Wharf Expansion Project (2011) Northern Territory Government

Tables and Figures

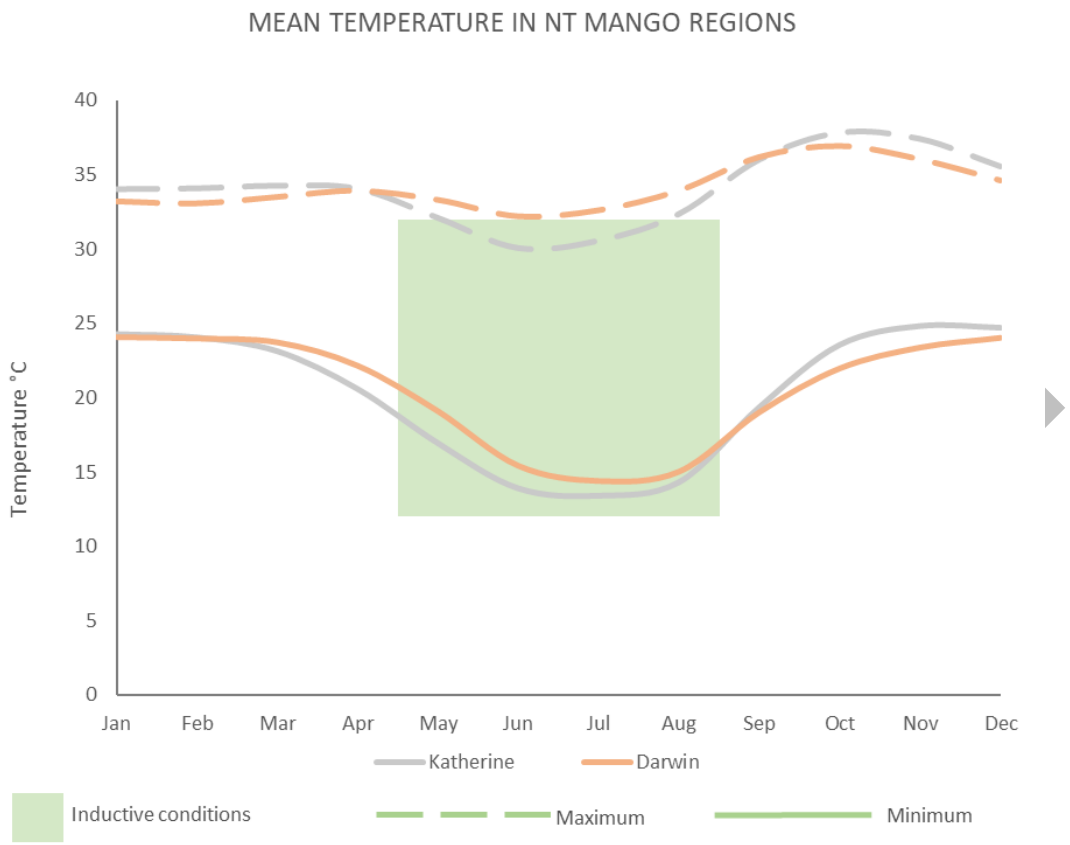

Figure 1. Mean minimum and maximum temperature for each month and floral inductive period for Katherine and Darwin mango production regions. Temperature data is monthly average maximum and minimum for the period of 1996 – 2019. Weather stations Middle Point (Darwin) and Tindal RAAF (Katherine). Data source: Australian Government Bureau of Meterology (BOM) 2020.

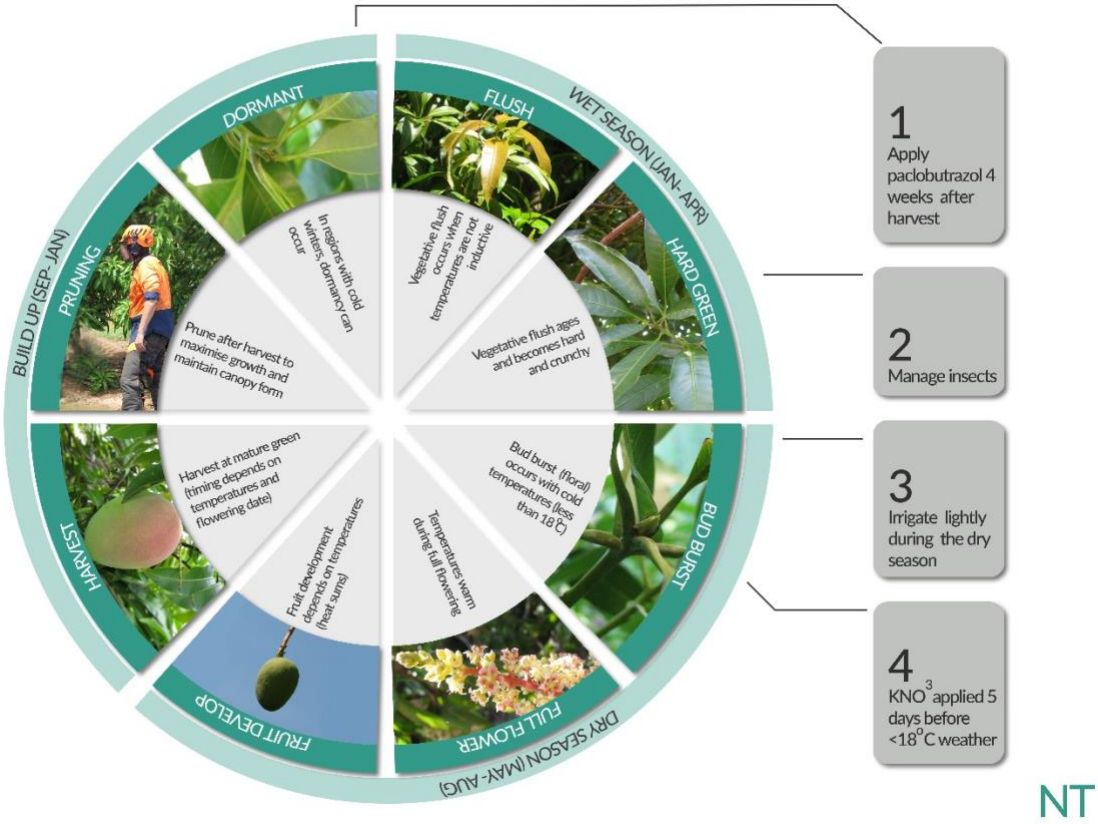

Figure 2. Annual flower management and phonological cycle for mangoes grown in the Northern Territory.

Figure 3. Mango flowers

Mango Flowering in Qld

Flowering in the mango production regions of Queensland (QLD) occurs throughout winter and into spring. However, flowering that occurs in early winter may not successfully set fruit due to reduced pollen viability, slow fruit growth and frosts. The ideal flowering time is during late winter to spring, from July to September. During this time, minimum temperatures have begun to rise but remain within the range of inductive conditions (Figure 1). Harvest in QLD begins in northern areas at Bowen/Ayr in early November, then Dimbulah from late November and Mareeba in early December. Harvest then moves to central and southern QLD in late December and January.

Annual production cycle

The annual production cycle for mangoes in QLD is largely influenced by cooling winter weather conditions from June – August. At this time, dormant shoots are stimulated to initiate floral shoot growth by these cool temperatures. If temperatures remain low for long periods, this may slow floral induction or result in flowers which are small and deformed, with reduced pollen viability and limited fertilization success. If temperatures remain high, shoots may not be stimulated to produce floral shoot growth and instead produce vegetative shoot growth or mixed floral/vegetative shoots. Early fruit development can also be limited by cold temperatures.

In QLD, floral shoot growth is first seen at Bowen/Ayr in early July, due to these regions rapidly cooling minimum temperatures (Figure 1). Peak flowering is often 2-3 weeks earlier here than at Mareeba. At Bundaberg, winter temperatures are much cooler and this often delays floral shoot emergence until early August. The arrival of warm spring temperatures from September – November at Bowen/Ayr further accelerates the growth of developing fruit within this region, with the fruit harvest often 3-4 weeks earlier here than at Mareeba.

Climate drivers for flowering

The timing and intensity of flowering within each region varies between years in response to variable climate patterns. Unseasonably warm or cold winters can result in reduced flowering, poor fertilisation and subsequent lower fruit yields. Seasonal climatic variability between regions can delay or accelerate flowering and fruit development, resulting in a change of harvest timing within a region. This can occasionally lead to the overlapping of harvest times between regions, which can result in unusually high fruit volumes on the marketplace at the one time and often low prices for the farmer.

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Management practices for QLD

Key management practices that promote mango flower induction in QLD are:

1. Increase irrigation during inductive conditions (July-September) to encourage floral shoot growth.
2. Protect flowers from frosts: design orchards that avoid trapping cool air and irrigate during light frosts.
3. Foliar applications of boron and potassium nitrate at bud break may increase flower number and vigour.

Key references

Australian Government Bureau of Meteorology (BOM). 2020. Monthly mean maximum temperature data for several locations. Retrieved from http://www.bom.gov.au/climate/data/

Litz, R. E. (1997). The *mango: botany, production, and uses*. New York: CAB International

MLA (2008) Weather drivers in Queensland

Technical Report, Chapter 7 Regional Climate of Northern Australia. East Arm Wharf Expansion Project (2011) Northern Territory Government

Tables and Figures

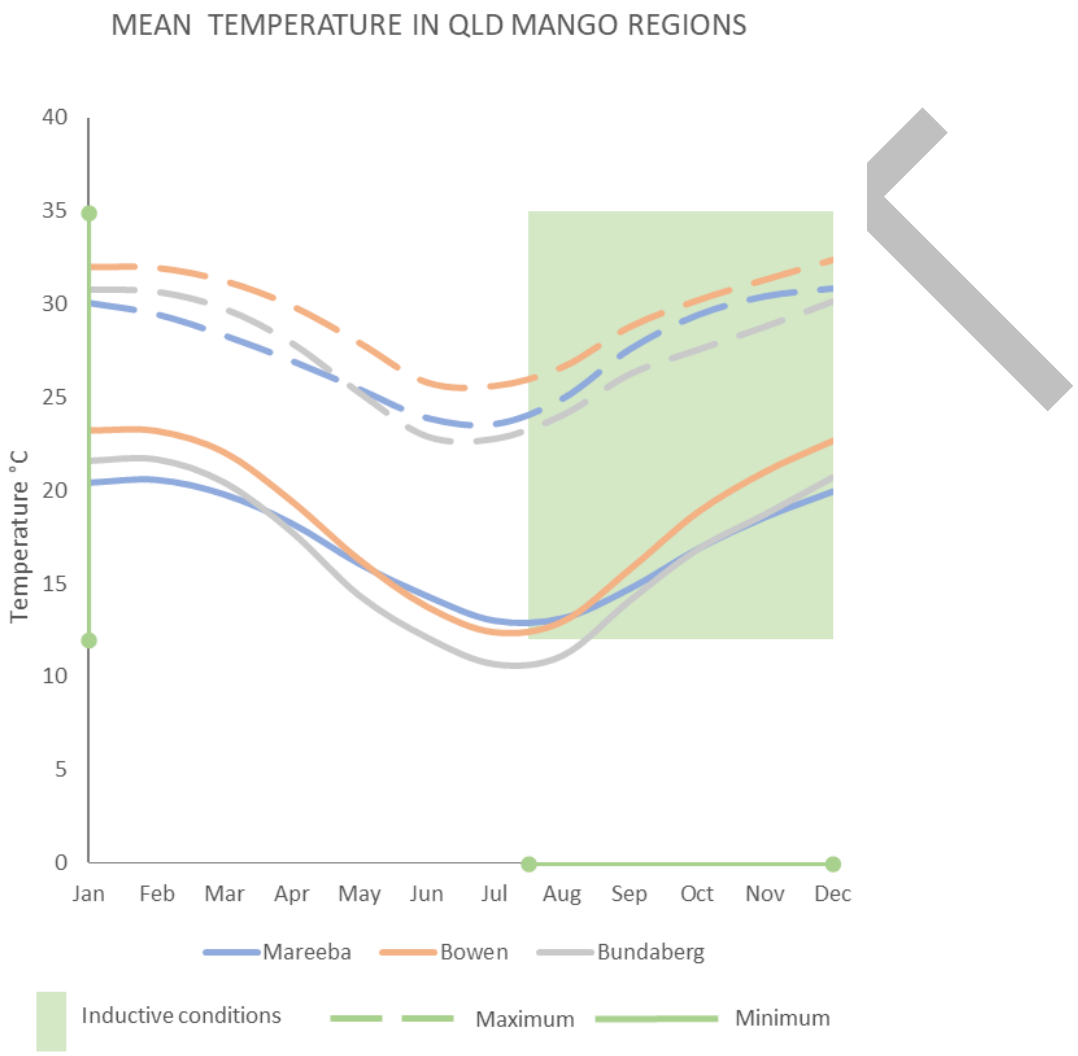

Figure 1. Mean minimum and maximum temperature for each month and floral inductive period of Mareeba, Bowen and Bundaberg mango production regions. Temperature data is monthly average maximum and minimum for the period of 1996 – 2019. Weather stations Ayr DPI Research Stn (Bowen), Walkamin Research Stn (Mareeba) and Bundaberg Aero (Bundaberg). Data source: Australian Government Bureau of Meterology (BOM) 2020.

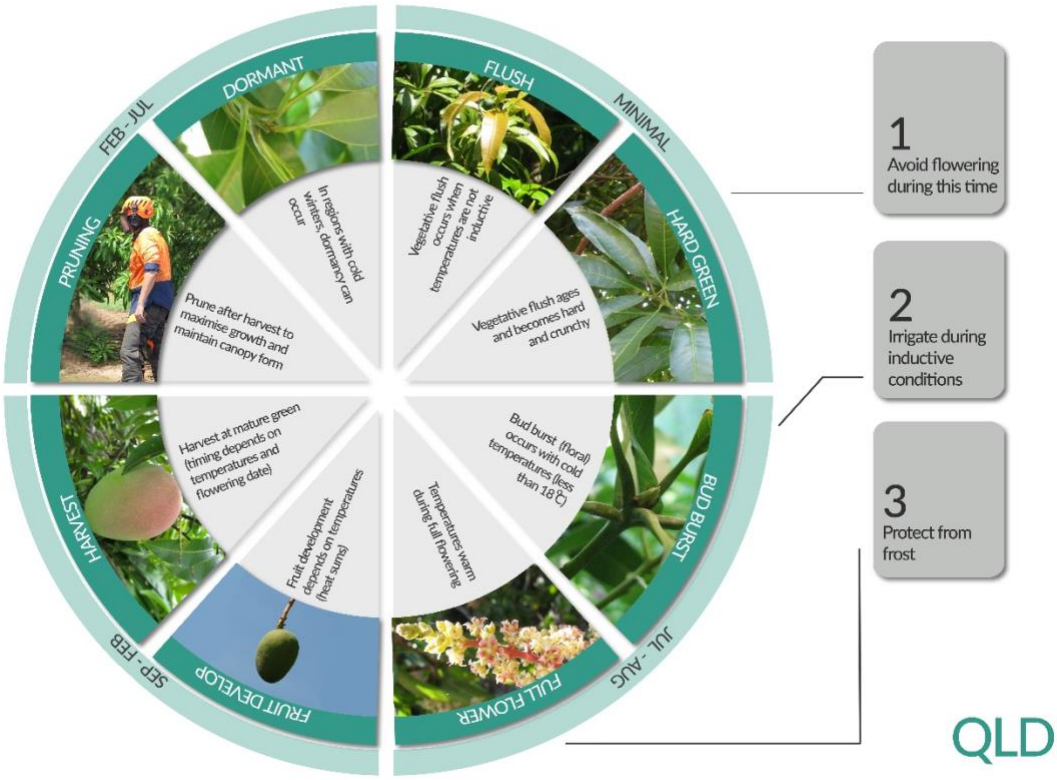

Figure 2. Annual flower management and phonological cycle for mango grown in the Queensland

Figure 3. Mango flowers

Mango Flowering in Western Australia

Mango production regions in Western Australia (WA) can be found in the far north around Kununurra, on the central coast near Carnarvon, and around Gingin (near Perth). The large geographical diversity of production regions in Western Australia dictates variability in the timing of flowering throughout the state. The earliest flowering occurs in Kununurra in June/July and continues down the coast to Gingin which flowers last around November/December. These late flowering regions in southern Western Australia correspondingly produce the latest fruit in the Australian production season.

Annual production cycle

The cooler climates of the southern production regions induce dormancy in mango trees followed by flowering in spring and an extended fruit development period. The production cycle in northern regions aligns with that of the Northern Territory.

Climate drivers for flowering

In the northern regions, consistently warm maximum temperatures ensure growth all year round. Occurrences of cool weather are restricted to a short period between May and September. This onset of cool weather occurs when high pressure systems in southern Australia direct cool dry south-easterly air streams to Northern Australia. This phenomenon can be observed and forecast in wind maps of Australia found on the Bureau of Meteorology website. The timing of arrival of cool weather in northern Western Australia can vary from year to year.

In southern regions, the arrival of warmer spring temperatures initiates bud growth whilst minimum temperatures are inductive, leading to flowering. Poor fruit set of flowering in spring can occur if temperatures are consistently low (i.e. ≤18°C) after flowering.

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Management practices for WA

Key management practices that promote mango flower induction in Western Australia are:

1. Northern WA;

    a. Preventing new vegetative growth immediately before flowering by limiting irrigation and avoiding nitrogen fertiliser application.
    b. Applying potassium nitrate (KNO_3) in the days before the arrival of cold weather.
    c. Applying paclobutrozol 4 weeks after harvest or up until mid-February.

2. Southern WA;

    a. Avoid an early winter flowering.
    b. Protect flowers from frosts: design orchards that avoid trapping cool air and irrigate during light frosts.
    c. Commence irrigation to encourage growth at the end of winter during inductive conditions.
    d. If required, at bud break apply boron and potassium nitrate.

Key references

Australian Government Bureau of Meteorology (BOM). 2020. Monthly mean maximum temperature data for several locations. Retrieved from http://www.bom.gov.au/climate/data/

Mangoes in Western Australia (2020) Department of Primary Industries and Regional Development, Western Australia

Tables and Figures

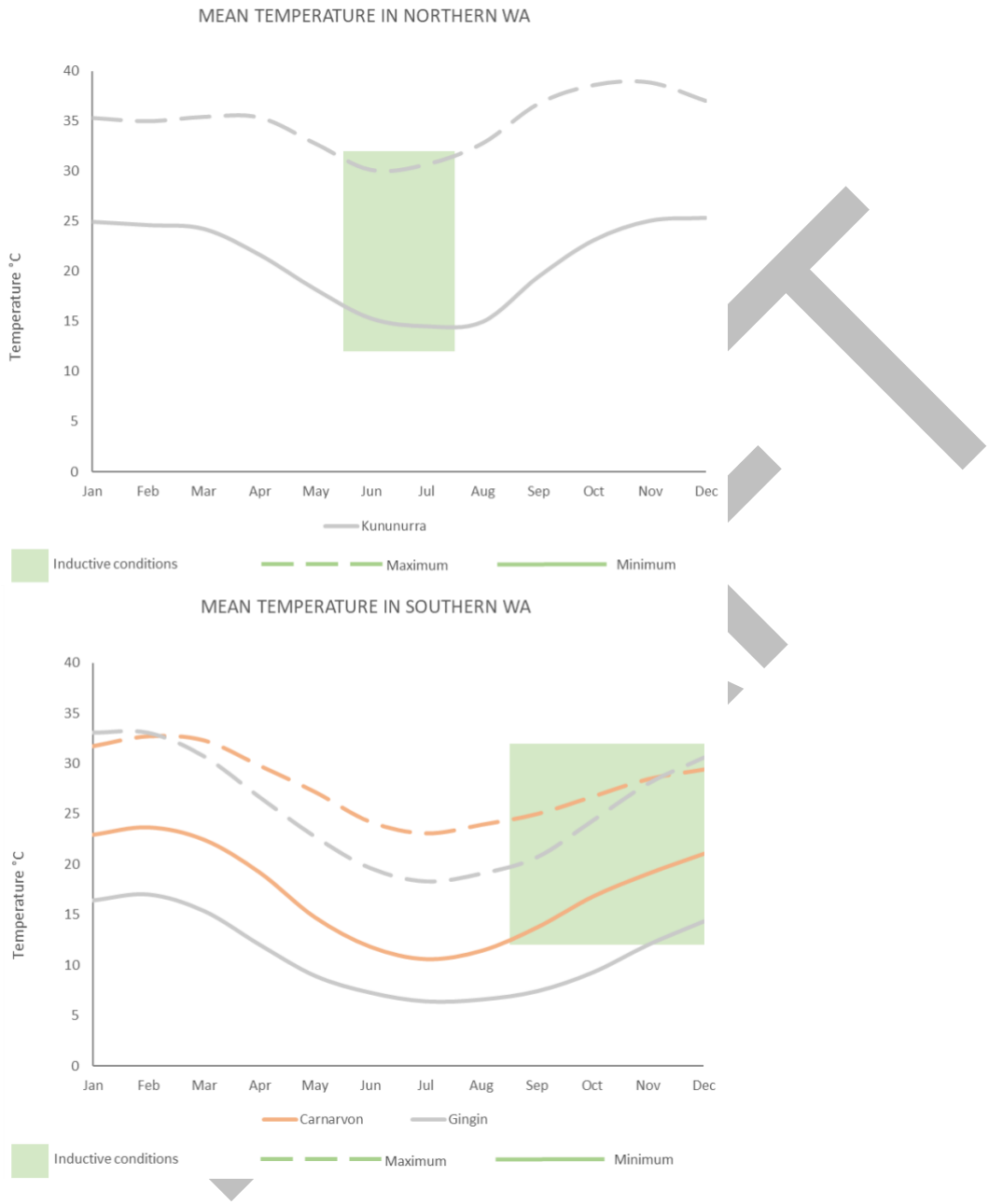

Figure 1. Mean minimum and maximum temperatures for each month and floral inductive period for Kununurra, Carnarvon and Gingin mango production regions. Temperature data is a monthly average maximum and minimum for the period of 1996 – 2019. Weather stations Kununurra Aero, Gingin and Carnarvon. Data source: Australian Government Bureau of Meterology (BOM) 2020.

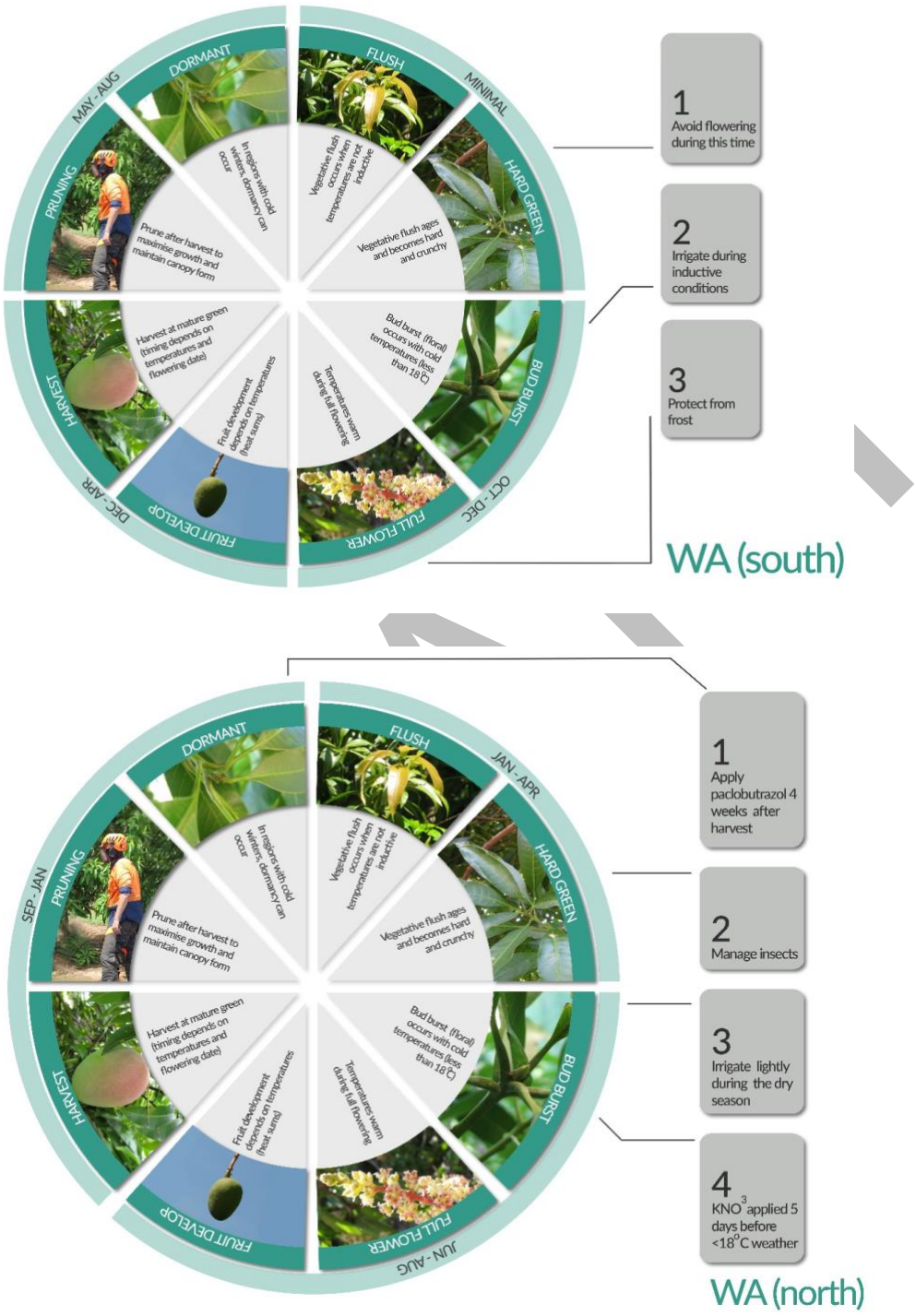

Figure 2. Annual flower management and phonological cycle for mango grown in Western Australia.

Figure 3. Mango flowers

Choosing mango tree spacing

In the early years of the Australian mango industry (1960s – 1980s) mango trees were regularly planted at low density spacings of 9m x 9m (30ft x 30ft) or greater. These wider spacings were required to accommodate vigorous mango tree growth and minimise overcrowding over the orchard lifetime. Almost all mangoes grown at this time were the vigorous Kensington Pride (KP) variety. The development of mechanised hedging equipment, the registration of plant growth regulators (PGRs), and improvements in orchard nutrition, irrigation and pruning practices have since enabled growers to maintain mangoes as smaller trees. Row and intra-row spacings have gradually reduced, resulting in increases in orchard tree densities per hectare.

Tree spacing is usually described as low, medium, and high density as follows:

Low density plantings (<200 trees/ha)

- Typically, of size: 9m x 9m = 123 trees/ha
- This spacing used in most Australian mango orchards established during the 1960s – 1990s
- Mature trees are usually tall (>4m) and have wider canopies (>6m)
- Lowest canopy surface area to volume ratio
- Lowest establishment and annual input costs per hectare
- Takes the longest to reach full production
- Lowest yields

Medium density plantings (200 – 500 trees/ha)

- Typically, of size: 8m x 6m = 208 trees/ha or 7m x 4m = 457 trees/ha
- Spacing used in most Australian mango orchards established 1990s to present
- Mature trees are usually <4m tall and canopies 4-6m wide
- This density can be managed with common farm equipment and systems
- Canopy growth managed using well-known techniques (hedging, PGRs)

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High – Ultra-high density plantings (500+ trees/ha)

- Typically, of size: 6m x 3m = 555 trees/ha; 5m x 3m = 666 trees/ha; 4m x 2m = 1250 trees/ha
- This spacing is uncommon, with highest densities only seen in some smaller commercial farms and research trials
- Mature trees are often short (<3m) and have narrow canopy width (<3m)
- Highest canopy surface area to volume ratio
- Highest establishment and annual costs per hectare
- Quickest to reach full production
- Highest yields
- Canopy growth is difficult to manage (particularly in vigorous varieties such as KP)

Before you start – spacing rules of thumb:

- Individual mango trees at mature size will often grow up to 50cm tall and 50cm wide every year after hedging, so allow for annual growth
- Farm machinery commonly requires a minimum 2 – 2.5m accessible inter-row space at harvest time for reliable and unhindered access
- To prevent excessive shading in fruit tree orchards, the desired tree height at harvest time should not be greater than 75% of the desired inter-row distance (e.g., if trees are expected to grow to 3.5m tall, then the minimum inter-row spacing should be 4.7m).

The decision on tree spacing is determined by four important considerations:

1. What is the mango variety?

Vigorous varieties such as KP have been difficult to manage in higher density systems due to their excessive vegetative growth rates. Plant growth regulators (PGRs), may help control tree vigour. Higher density systems suit less vigorous varieties such as Calypso®, R2E2, Honey Gold and Keitt, which may still grow up to 50cm tall and 50cm wide every year after hedging.

2. What is the target inter-row machinery width?

Farm machinery commonly requires a minimum of 2 – 2.5m accessible inter-row space at harvest time for reliable and unhindered access. Inter-rows may need to be even wider in cases where farm equipment has extra space requirements (e.g., certain orchard sprayer set-ups). Allowances should be made to allow for annual lateral canopy growth, from hedging to harvest time, which makes the inter-row progressively narrower over the season.

3. What is the target tree harvest height?

If harvesting is to be conducted via hand-picking from the ground or by only using short picking sticks, then a harvest height of <3.2m is necessary. Harvesting trees >3.2m requires different picking practices which are generally slower and more expensive. These include the use of longer picking poles, cherry pickers or elevated harvest aid platforms. Taller trees require wider inter-rows to minimise shading.

4. What is the target tree harvest width?

The width of the tree is a more complex decision and is greatly influenced by the tree intra-row distance. If the trees are planted at wider distances along the tree row, then trees need to be allowed to grow to a greater width to ensure that they fill-out the hedge faces sufficiently to enable optimum fruiting. Trees planted at wider spacings (e.g., 5 – 6m) will need to be allowed to grow to wider widths/diameters to fill-out these hedge faces. Trees planted at close intra-row spacing (e.g., 2 – 3m) may only need to grow to 2 – 3m width/diameter to reach optimum fruiting dimensions.

Current Australian industry trends

New mango orchards in Australia are being primarily established as medium density systems usually between 200 – 400 trees/ha. Most of the new plantings include less vigorous varieties such as R2E2, Keitt, Honey Gold™ and Calypso®. The target tree heights at harvest within these new orchards are becoming increasingly shorter (often now around 2.5 – 3m) due to the economic and workplace efficiencies of harvesting low-hanging fruit. The target inter-row machinery access widths are fairly wide, often around 4 – 5m, which accommodates traditional

wider spaced machinery, spray equipment and harvest aids. Target tree widths at harvest are also fairly wide, often around 3 – 4m.

Spacing opportunities

The trend towards much smaller tree heights provides new opportunities for increased planting density and the potential for increased orchard profitability. The first opportunity is through reductions in the target inter-row machinery access widths, which has been made possible by world-wide trends in the adoption of smaller and narrower orchard machinery and equipment for fruit tree management. The second opportunity is to reduce target tree widths at harvest by planting trees more closely within the row. Mango trees are quite cheap to purchase from the nursery (~$20/tree) and planting at closer spacing reduces the time it takes for orchards to reach their optimum size, and hence maximum fruit production capacity. Research and farmer trials with varieties such as R2E2, Keitt and Calypso® have found with careful management, mature orchards can be maintained continuously and with high productivity, at narrow tree widths (2 – 3m).

More information

For more information on high density mango orchards visit the Queensland Agriculture's YouTube channel to view the video 'High-density mango orchards: slim hedges'.

Economics of high-density mango orchards

Results from the Small Trees High Productivity Initiative at the Queensland Department of Agriculture and Fisheries (DAF) Walkamin Research Facility near Mareeba, are demonstrating that mangoes can be grown with high productivity at high densities, using both traditional hedging and trellising methods. Varieties studied include Calypso®, NMBP-1243 and Keitt. Seven years of yield and management system input data have now been collected. Calypso® yield data is presented in Figure 1. Trial results are showing that the extra costs of establishing trees at higher densities can be quickly recouped via greatly increased early yields per hectare, resulting in increased orchard profitability from an early age.

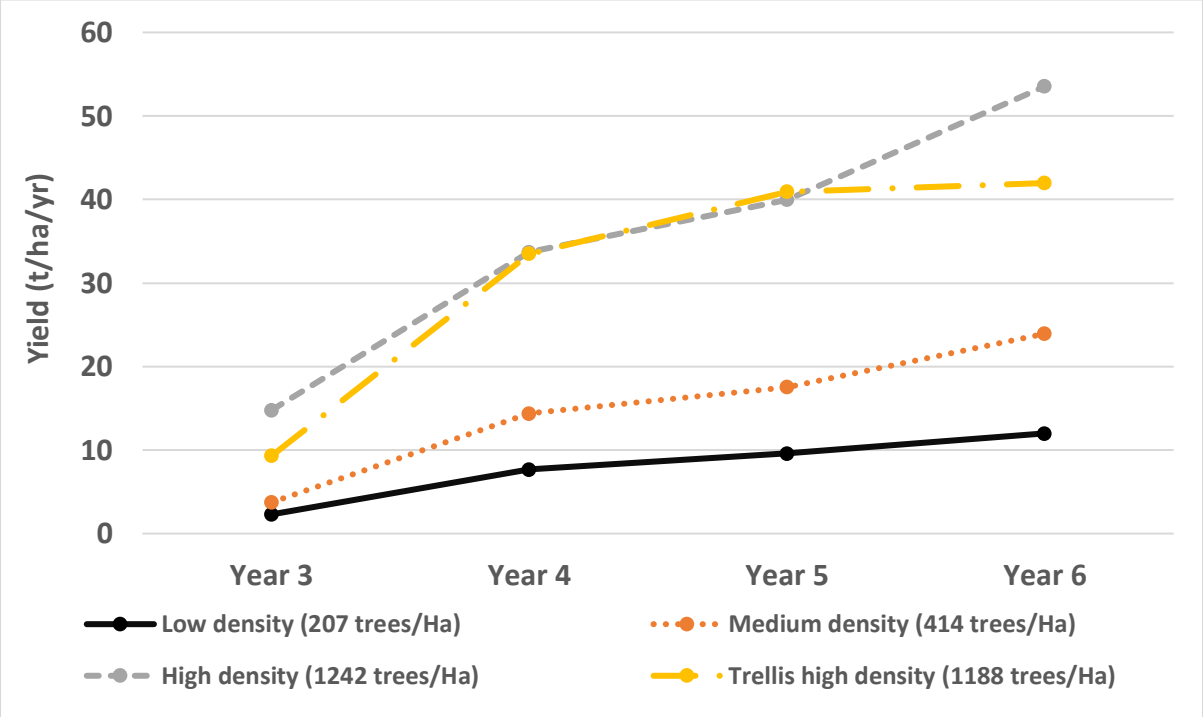

Figure 1. Calypso® yields (t/ha) to age 6 years, for 4 mango density systems at the DAF Walkamin Research Facility.

Gross margin analysis

A gross margin analysis of a range of intensive mango systems was undertaken that compared conventional mango planting systems at three different densities – low (207 trees/ha), medium (408 trees/ha) and high (1242 trees/ha) and one trellised planting system at high density (1188 trees/ha). The mango variety B74 (Calypso®) was selected as the

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focus variety for the study. This analysis used data from the DAF Planting System Trial (PST), the Australian mango industry, growers, industry stakeholders and published reports.

The following were the per hectare costs and returns expected for each of the planting systems: Low, medium, high density conventional and high-density trellis. The gross margin is the difference between the costs and returns at full production. The costs and returns used in this calculation are outlined in Table 1. The gross margin does not consider fixed costs or capital expenditure. Growers considering transitioning all or part of their farm to a higher density planting system or developing a new farm at increased density should consider undertaking a complete economic analysis specific to their situation.

Table 1. Annual yields and gross margin ($/ha) calculated at full production

Item	Assumptions	Conv. low density 207 trees/ha	Conv. medium density 408 trees/ha	Conv. high density 1,242 trees/ha	Trellis high density 1,188 trees/ha
Yield (tonnes/ha)					
Total yield	Total tree yield	18.2	32.6	58.8	65.9
Harvested yield - HY	5% fruit left in paddock	17.3	31.0	55.9	62.6
Income ($/ha)					
Premium	$4.00/kg @ 77% of HY	53,300	95,505	171,893	192,958
Class 1	$2.00/kg @ 14% of HY	4,845	8,682	15,627	17,541
Class 2	$1.57/kg @ 4% of HY	1,087	1,947	3,505	3,934
Juice/processing	$0.50/kg @ 4% of HY	346	620	1,116	1,253
Reject	$0.00/kg @ 1% of HY	0	0	0	0
Total income ($/ha)		**59,578**	**106,754**	**192,141**	**215,686**
Variable costs ($/ha)					
Nutrition		1,410	2,106	3,132	3,016
Pest management		3,984	5,415	3,478	2,913
Disease management		4,560	6,366	3,179	2,706
Weed management		526	754	876	876
Irrigation		634	1,161	1,576	1,404
Canopy management		1,990	3,587	7,706	6,346
Harvesting		2,933	4,694	8,449	9,485
Packing		11,726	20,806	37,245	41,782
Freight to market		4,391	7,867	14,160	15,895
Commissions & Levies		6,283	11,259	20,264	22,747
Total variable costs ($/ha)		**38,437**	**64,015**	**100,065**	**107,170**
GROSS MARGIN (Total income – Total variable costs)		**21,138**	**42,738**	**92,071**	**108,514**

Table 2 outlines the establishment costs required for setting up each of the four systems. Included in the capital outlay costs were land preparation including boom spraying, slashing, ripping and levelling the block in preparation for planting; Irrigation, including materials, labour and installation of mainline, sprinklers, taps, connectors and pump and associated infrastructure; Planting expenses included the cost of trees, pre-plant lime and application and tree planting labour; and for the trellis system, the trellis infrastructure.

Table 2. Establishment costs per hectare for the four planting systems

Planting system	Land Prep.	Irrigation	Planting	Trellising	Total
Conventional low density	$1,100	$5,800	$3,591	-	$10,491
Conventional medium density	$1,262	$7,513	$7,078	-	$15,853
Conventional high density	$1,262	$12,676	$21,549	-	$35,487
Trellis high density	$1,262	$12,792	$20,612	$31,981	$66,647

The full CRCNA report 'Economic Case Study of Intensive Mango Systems: A comparison of the profitability of conventional (low, medium & high-density) and trellis (high-density) mango canopy systems in north Queensland based on early trial results', is available at the above link or can be found on the Cooperative Research Centre for Northern Australia's (CRCNA) website under Resources > Publications > An economic case study of intensive mango systems.

Key references

Bennett, D. M., and Dickinson, G.R. (2021). Economic case study of intensive mango systems: A comparison of the profitability of conventional (low, medium and high density) and trellis (high density) mango canopy systems in north Queensland based on early trial results. https://crcna.com.au/resources/publications/economic-case-study-intensive-mango-systems. 28pp.

High-density hedge (slim-hedge) design, pruning and training

What is a slim hedge?

Hedges are defined by allowing neighbouring tree canopies to touch along the intra-row, achieving a wall of vegetation and fruit along each lateral face (Figure 1a). Hedge systems may occasionally (e.g., every 1-3 years) have the intra-row tree canopies pruned back between neighbouring trees, if canopies become entangled or too dense, and usually have some internal vegetation removed every year. Mango hedge systems are not a new concept and older, wide-spaced trees have often been allowed to grow into hedges. Wide-spaced hedge designs, however, are often characterised by wide canopy widths, resulting in large voids within the trees, which can harbour pests and diseases and are less efficient for pesticide management practices. The new high-density hedge systems are characterised by very narrow canopy widths (Figure 1b). These hedge systems are known as 'slim-hedges'. They have lower row canopy volumes per hectare, but higher canopy surface area per hectare, than low density systems.

For a video on slim hedge orchard designs and considerations please view the High-density mango orchards: slim hedges video on the Queensland Agriculture YouTube channel.

(a) (b)

Figure 1a. Example of a slim hedge orchard planted in the 1990s at Bowen with average yield of 30-38 tonnes/ha; Figure 1b. Slim hedge orchards are characterized by narrow canopy widths of less than 3m.

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Slim-hedges have the following advantages over wider-spaced hedge or conventional systems:

- Greater orchard canopy surface area per hectare provides greater photosynthetic capacity per hectare
- Greater canopy surface area per hectare means more sites for flowering and fruit production, resulting in higher yields
- Lower tree volume per hectare requires less pesticide spray volume per hectare, thus reducing pesticide input costs and improving efficiencies
- Lower tree volumes per hectare reduces harbourage sites for pests and diseases
- Improved harvesting efficiency. Fruit harvested from short, narrow trees, are more easily and rapidly picked from the ground, either by hand or with short picking sticks, than larger trees
- Efficient use of site resources and input costs

Figure 2. Many growers now use harvest aids when picking. The small Keitt mango trees in this orchard are fast and easy to pick, with the harvest aid applying Mango Wash® toprevent sap burn, before depositing the mangoes into a half-tonne bin.

Principles of slim-hedge orchards

- Tree canopies are maintained as narrow hedges no more than 2 – 3 metres wide
- Trees are planted no more than 2 – 3 metres apart within the row
- Trees are regularly tip-pruned during the establishment years to maximise the number of tertiary fruiting terminals
- Mechanical hedging along the row is implemented early (from approximately year 4 onwards) to maintain the canopy at no more than 2 – 3 metres wide. Mechanical pruning is used to remove only one year of growth to 're-set' the tree each year (Figure 3).
- Maximum tree height is reached by 6 – 7 years and is maintained with mechanical pruning
- Pruning between trees along the row is only necessary every 2 – 3 years.

Figure 3. Post-harvest mechanical pruning is a common practice in Australian mango orchards.

Considerations when planning a slim-hedge orchard

- Sprinkler irrigation systems may be less suitable to high density slim hedge designs due to their smaller canopies and dripline. Consider discussing alternative options - such as dripper systems - with your irrigation supplier.
- A narrower canopy means a less-powerful spray rig is needed to achieve adequate canopy coverage. Alternatively, operators can increase tractor speed when spraying, resulting in savings on labour, chemical and running costs.
- If the hedge face has gaps between trees, trial techniques such as pruning or cincturing to encourage branching to fill gaps. Branches may also be trained using weights or tied to neighbouring trees to encourage growth to fill voids.

Can you retrofit existing low-density orchards?

Retrofitting low density orchards by inter-planting between existing trees is possible but is not without challenges (Figure 4). The newly planted, young trees compete for light and site resources with the larger, established trees and may suffer from higher pest pressure, resulting in poorer thrift. Instead, it is worth considering transitioning to a high-density orchard using a staged approach a block or two at a time. This allows trialing higher planting densities on a small scale to assess the management requirements and economic benefits before implementing it across the entire farm. It also maintains an income stream from existing blocks while the newer high density blocks reach maturity. Ongoing renewal of orchards every decade or two, also means new mango varieties can be incorporated into the farming system.

Figure 4

Figure 4. Low-density orchards, such as this one, are being phased out as the Australian mango industry transitions to higher density planting systems. Retrofitting low density orchards by inter-planting young trees within rows or adding new rows between existing rows, would present management and productivity challenges. Instead, consider a staged approach where old trees are removed a block at a time and replaced with new blocks of higher density plantings.

Making the change to high density mango orchards

Why intensify?

Maintaining profitability in an environment of ever-increasing costs is a major challenge facing Australian mango growers. A key priority for the Australian mango industry is to increase industry productivity per hectare through increased yields and reduced costs (Hort Innovation, 2017). To achieve these goals, improved productivity is essential, however, this is challenging with conventional planting densities often less than 200 trees per hectare. Yields per hectare vary annually, but on average, Kensington Pride (KP, the main industry variety) yields 35 – 70kg per tree or 7 – 13 tonnes per hectare at a spacing of 185 trees/ha (DPI, 1999). Opportunities exist to improve productivity through intensification.

An intensification program within the apple and pear industry (Future Orchards®) initiated in 2006, has substantially increased industry average production from 10-20 up to 35-55 tonnes/ha, with some orchards achieving over 100 tonnes/ha (Crawford, 2016). This success has been achieved through the adoption of new canopy systems including trellis and non-trellis designs, which incorporate smaller trees, grown at higher densities, with narrow, more open canopies. These systems increase canopy surface area per hectare and improve light interception and light distribution, which in turn results in improved productivity.

Figure 1. Apples grown on trellis systems. The success of high-density orchards in the apple and pear industries (Future Orchards®) has inspired high density trials in other tree crops, including mango.

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Challenges for mangoes

High density systems also have great potential for mango orchards, however, one of the main challenges posed by intensifying mango trees is vigour control (Bally and Ibell, 2015; Menzel & Le Lagadec, 2017). Most mango varieties grown in Australia are vigorous (particularly Kensington Pride) and if left unmanaged can easily grow to heights greater than 10m. The use of trellising and/or intensive branch training and pruning methods has been successfully used as a tool by the apple and pear industry to manage vigour (Crawford, 2016). These methods may also enable mango orchards to be grown at higher densities and significantly improve productivity. Other expected advantages of smaller trees grown at higher densities include; more efficient harvesting, better adaptation to mechanisation and robotics, greater efficiency of pest and disease management (Bally and Ibell, 2015; Bally *et al*., 2020; Menzel & Le Lagadec, 2017) and greater cyclone resilience (Drinnan *et al.* 2018).

Figure 2. The Kensington Pride mango variety is extremely vigorous, making it less suitable for high density orchards.

Industry adoption

The Australian mango industry has experienced a gradual shift towards increased planting density over the past 20 years, as new varieties with less vigour than KP have been planted. These include R2E2, Keitt, Honey Gold™ and Calypso®. There are a number of established, well managed R2E2 and Keitt orchards with up to 555 trees/ha. Semi-dwarf varieties such as Calypso®, have been commercially planted at densities up to 357 trees/ha.

Figure 3. An example of an R2E2 mango orchard in Bowen, Queensland, planted over 20 years ago at high density (6x3m or 555 trees/ha).

Research Trials

A study by Drinnan *et al*. (2018) found that mangoes grown at Mareeba under a high-density trellis system (5x3m) also showed good applicability to this system. In response to these national orchard system trends, the Queensland Department of Agriculture and Fisheries (DAF) commenced the Small Tree High Productivity Initiative in 2012. This initiative aims to help transform tropical and sub-tropical fruits from low-yielding, low density orchards into high yielding, high density orchard systems. Under this initiative and with funding support from Hort Innovation using the cross-industry R&D levy, a large, replicated, planting systems trial (PST) was established at the DAF Walkamin Research Facility in 2013, incorporating three mango varieties grown at a range of planting densities using conventional and trellis methods. Early results from this trial have been very promising and suggest mangoes have high potential for improved productivity when grown in higher density systems (Bally *et al*., 2020).

Figure 4. A mango planting systems trial that includes trellised and non-trellised planting densities of 1250 trees/ha has been running at Walkamin Research Facility since 2013. The new hybrid variety NMBP-1243 (pictured) is one of three varieties being trialled, along with Calypso® and Keitt.

Table 1. Advantages and disadvantages of high-density mango orchards

Advantages	Disadvantages
Higher yields/ha	Higher establishment costs per hectare
Greater input efficiency per kg of fruit produced	Higher early management costs per hectare
Higher profitability	More management complexity
Smaller trees are easier to harvest	Cannot use large machinery
Suited to robotic harvest technology	More pruning required
More efficient pesticide use per hectare	Requires staff training
Less prone to cyclone damage	Difficult to manage tree vigour
	Risks of greater fruit sunburn

Economic implications

Adopting a new orchard management system poses numerous risks, but of chief concern among growers are the economic implications of this decision. High density systems – particularly trellis systems – require significant upfront investment in infrastructure and additional labour for pruning and training. In new systems, these costs are challenging for growers to accurately estimate, and subsequently make informed decisions about moving to higher density designs.

For more information on the economic implications of high-density orchards, see the Economics of high-density mango orchards fact sheet. For a gross margin analysis see the CRCNA report 'Economic Case Study of Intensive Mango Systems: A comparison of the profitability of conventional (low, medium & high-density) and trellis (high-density) mango canopy systems in north Queensland based on early trial results', available at the above link or at the Cooperative Research Centre for Northern Australia's (CRCNA) website under Resources > Publications > An economic case study of intensive mango systems.

Key references

Bally, I.S.E. and Ibell, P.T. (2015). Improvement of mango tree architecture. Acta Horticulturae, 1075, p59-64.

Bally, I.S.E., Ibell, P., Mahmud, K., Wright, C., Mizani, A., and Wilkie, J. (2020). Benefits of intensive production systems in mango. Acta Horticulturae, 1281, p 493-498

Bennett, D. M., and Dickinson, G.R. (2021). Economic case study of intensive mango systems: A comparison of the profitability of conventional (low, medium and high density) and trellis (high density) mango canopy systems in north Queensland based on early trial results. https://crcna.com.au/resources/publications/economic-case-study-intensive-mango-systems. 28pp.

Crawford, A. (2016). Final Report – Future Orchards 3. AP11017. Hort Innovation, 24pp

Department of Primary Industries and Fisheries (1999) Mango Information Kit. Agrilink, your growing guide to better farming guide. Eds. Kernot I, Meurant, N., Holmes, R., MacLeod, N., Fullelove, G. and Bally, I. Manual. Agrilink Series QAL9903. Department of Primary Industries, Queensland Horticulture Institute, Brisbane, Queensland.

Drinnan, J., Wiltshire, N., Diczbalis, Y., Holden, P., and Thompson, M. (2018). Improving the capacity of primary industries to withstand cyclonic winds. AgriFutures Australia, New South Wales.

Menzel, C. M., Le Lagadec, M. D. (2017). Can the productivity of mango orchards be increased by using high-density plantings? Scientia Horticulturae, 219, 222-263. https://doi.org/10.1016/j.scienta.2016.11.041

Plant growth regulators

Plant growth regulators (PGRs) can be used in combination with other management practices, such as pruning, to aid in canopy management. The most common PGR used in the mango industry is paclobutrazol (PBZ). PBZ is in the triazole chemical group. Triazoles inhibit the production of gibberellin, a plant hormone responsible for cell elongation. Application of PBZ after post-harvest pruning, results in reduced internode lengths of new shoots, helping to control vegetative vigour. Paclobutrazol applied at this time may also promote greater flowering* and may also reduce alternate bearing in some mango varieties. The understanding is that reducing vegetative vigour frees up carbohydrate resources that can be allocated to flowers and fruit. The use of plant growth regulators should be carefully managed and monitored, as undesired outcomes are not uncommon. For example, flower panicles may become excessively compact and require treatment for webworm if paclobutrazol is applied later than recommended.

*For more information on how paclobutrazol has been used to manipulate flowering in the Top End, see – NTDITT's factsheet on Flowering and Fruiting in the Top End with Paclobutrazol.

When to apply

As per the label instructions, application is recommended once per year within four weeks after harvest and no later than mid-February. Prior to and after application, ensure trees are well watered and only apply if the trees are healthy and not under any stress. It is not recommended to treat young trees that have a canopy of less than 3 metres in diameter.

NOTE: At the time of publication, according to the APVMA website, products containing paclobutrazol are only registered for use in mango in Queensland, Northern Territory and New South Wales. Always follow all directions on the label.

How to apply

Apply as per the label instructions as a collar drench mixed with 0.5 to 2.0 litres of water onto the soil/trunk crack line evenly around the base of the trunk.

Retreatment

Treatment effects can last more than one season and can differ with soil type. For sandy soils, do no retreat until after normal growth has resumed. For clays and red volcanic soils, retreatment can be undertaken each year, however if growth units become progressively more compact, postpone treatment and do not retreat until normal growth has resumed.

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Rates

Table 1. Application rates for paclobutrazol where active constituent of product is 250 g/L

Tree Age (years)	Soil type	Rate per tree (mL)
3 – 6	Light sands	8 - 12
	Clay, red volcanic	12 - 16
6+	Light sands	16 - 20
	Clay, red volcanic	20

Key references

APVMA (2022). APVMA PubCRIS database. https://portal.apvma.gov.au/pubcris

Bhatla, & A. Lal, M. (2018). *Plant Physiology, Development and Metabolism* (1st ed. 2018.). Springer Singapore. https://doi.org/10.1007/978-981-13-2023-1

Litz, R. E. (1997). *The mango: botany, production, and uses*. New York: CAB International

Pruning mature trees

The aim of canopy management is to develop and maintain a productive fruit-bearing face. An ideal mature mango tree has an open canopy, is small enough to pick easily and has many fruiting terminals. Mature mango trees are pruned for a variety of reasons:

- Control tree size
- Maximise fruiting terminals
- Improve spray penetration
- Improve fruit colour
- Synchronise and encourage flushing
- Remove dead and diseased wood
- Improve access

Control tree size

Mango trees are vigorous and if growth is not managed can reach heights of over 10 metres at maturity. Trees of this size result in inefficient fruit harvesting and poor pest and disease management. This means poorer quality fruit and lower yield per unit area.

Maximise fruiting terminals

Mangoes are apical flowerers, meaning they flower from their tips. Pruning encourages branching, and the more branches the tree has, the greater the bearing potential. If tips are pruned off in winter, mangoes can also produce flowers from leaf buds (axillary flowering) just below the tips.

Improve spray penetration

Better spray penetration reduces the impacts of pests and diseases, meaning better quality fruit. Better quality fruit receives higher prices resulting in improved profitability.

Improve fruit colour

Removing internal branches that are causing over-crowding leads to greater light penetration. Improved light penetration results in better blush on fruit, particular fruit growing

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in the internal parts of the tree. Greater light interception and utilisation by the tree may also improve yields.

Synchronise and encourage flushing

Mangoes are notorious for asynchronous flushing, flowering and fruiting. These and other traits are a consequence of the evolutionary adaptations developed in response to the tropical, highly seasonal environment in which the mango evolved. Pruning after harvest can help to synchronise shoot growth to achieve more uniform flowering, bringing trees into a regular, predictable cycle that is better suited to commercial production.

Remove dead and diseased wood

As with all fruit-tree crops, pruning forms an essential component of good farm hygiene by removing the dead or diseased wood that could compromise the health and productivity of your orchard.

Improve access

Weed control, irrigation, fertiliser application, harvesting and pest & disease control all require good access between rows to be efficient and effective.

Equipment required

To hand prune mature mango trees, you will need a good pair of secateurs for cutting smaller branches and suckers. For larger branches up to 50mm diameter, lopping shears are recommended. The use of a pruning saw is recommended for large branches and trunks up to 150mm in diameter. A chainsaw may also be used for very large branches and trunks, being sure to adhere to workplace health and safety guidelines.

When to prune

The main prune is conducted immediately after harvest. This is usually completed using a combination of mechanical pruning with a hedging machine (pictured) and hand pruning. Many growers perform a secondary prune at the beginning of the winter dormancy period to remove any internal branches and sucker growth.

Regional pruning practices

In Northern NSW where trees often only crop every second year, they are mechanically and hand pruned heavily on the year they won't crop and only hand pruned the year they will bear a crop.

In Kununurra where it is very hot and harsh and where the air is dry, growth rates are low and branches/fruit are highly susceptible to sunburn. Large canopies are maintained to cope with the severe conditions, particularly over the summer/wet season.

Gingin has cold winds and mild summers with heat waves so there is limited growth/flush on trees compared to other growing regions.

Carnarvon presents similarities to both Kununurra and Gingin.

How to prune: hand pruning

Hand pruning techniques will vary, depending on the variety grown and the tree's condition. Pruning is best done each year immediately after harvest. This involves the following steps:

1. Cut back branch terminals to behind a growth node. Remove all but two or three well-spaced shoots from branch tips. Keep the trees to a diameter that allows machinery to travel between the rows and allows trees to just touch within the rows.
2. Cut upward growing branches roughly 30-50cm below the height you want the tree to be at harvest. Depending on variety, mango trees will grow vertically 30 to 50 cm from hedging to harvest time.
3. Remove any low growing branches that are likely to interfere with under-tree access for irrigation or weed control
4. Open up the interior of the tree by removing some of the branches where growth is crowded. Remove shoots that are not exposed to sunlight. Thin out canopy in dense trees to allow spray penetration and to improve light penetration and air circulation.
5. To maintain tree size and encourage a well branched canopy, branches should be cut back behind the node. This is particularly important for varieties that have strong

apical dominance such as Keitt. The branches on these varieties must be cut back regularly to improve tree shape.

6. Remove dead or diseased branches and dead inflorescences.
7. Paint the top side of all exposed branches with white water-based or plastic paint to prevent sunburn.

How to prune: mechanical pruning

Pruning costs can be greatly reduced with the use of mechanical saws. Most growers utilise pruning contractors that have specialised hedging machines to undertake annual hedging immediately after harvest. Usually only the tip growth is removed. Trees that are mechanically pruned have a square or rectangular shape, with the four sides and top trimmed flat.

Some hand pruning is still necessary after machine pruning, particularly on the inside of the tree.

It is important to ensure adequate water and nutrition is available to the tree to support the post-harvest flush following hedging. Discuss a nutrition program with your agronomist and/or refer to the factsheet 'Understanding mango crop nutrition: A guide for Australian mango growers' available on the Australian Mangoes Best Practice Resources website.

Factors impacting plant response to pruning

Leaf nitrogen levels above 1.4% at the time of pruning, combined with adequate water availability is likely to result in two or three post-harvest vegetative flushes. If a late flush does occur, this reduces the likelihood of a good flowering event following the winter dormancy period, even with a foliar application of potassium nitrate. It is therefore important to monitor leaf nitrogen levels to ensure they are between 1.1 and 1.4% before pruning.

Removing branches larger than 1cm in diameter is also likely to result in two or more vegetative flushes. If the aim is to rejuvenate an aging orchard, it may be necessary to undertake severe pruning. The decision to undertake this type of pruning should be weighed against the potential negative productivity impacts. Some growers opt for a staged approach, severely pruning one side of the tree one season and the other side the following season.

Key references

Department of Primary Industries and Fisheries (1999) Mango Information Kit. Agrilink, your growing guide to better farming guide. Eds. Kernot I, Meurant, N., Holmes, R., MacLeod, N., Fullelove, G. and Bally, I. Manual. Agrilink Series QAL9903. Department of Primary Industries, Queensland Horticulture Institute, Brisbane, Queensland.

Devonport, T. L. (2006). Pruning strategies to maximize tropical mango production from the time of planting to restoration of old orchards. *Horticultural Science, 41*(3), 544-548.

Oosthuyse, S. A. (1995). Pruning of mango trees: An update. *South African Mango Growers' Association Yearbook,* 15, 8pp.

Poffley, M., & Owen, G., (2006). Agnote D15: Mango pruning in the Top End. Department of Primary Industry, Fisheries and Mines, Northern Territory Government, Darwin, Northern Territory.

Pruning young trees

Young mango trees are pruned to ensure that the tree develops a strong framework with plenty of exterior terminal branches and minimal interior branches. As the mango tree is a terminal bearer (it flowers from the ends of the branches), the more branches the tree has, the better the potential yield. Pruning young trees frequently also brings the trees into production earlier than if they were left unpruned.

A well-structured tree:

- is easier to harvest
- has better spray penetration which improves fruit quality
- has more branches and therefore higher yields

Natural growth habit of young mango trees

Young mango trees have two distinct growth phases:

1. Seedling development (a)
   - Most energy is directed to lengthening the main stem
   - May grow to over one meter tall before pushing out branches
2. Lateral branching (b)
   - Development of the canopy

(a)

(b)

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Equipment required

To prune young mango trees, you will need a good pair of secateurs.

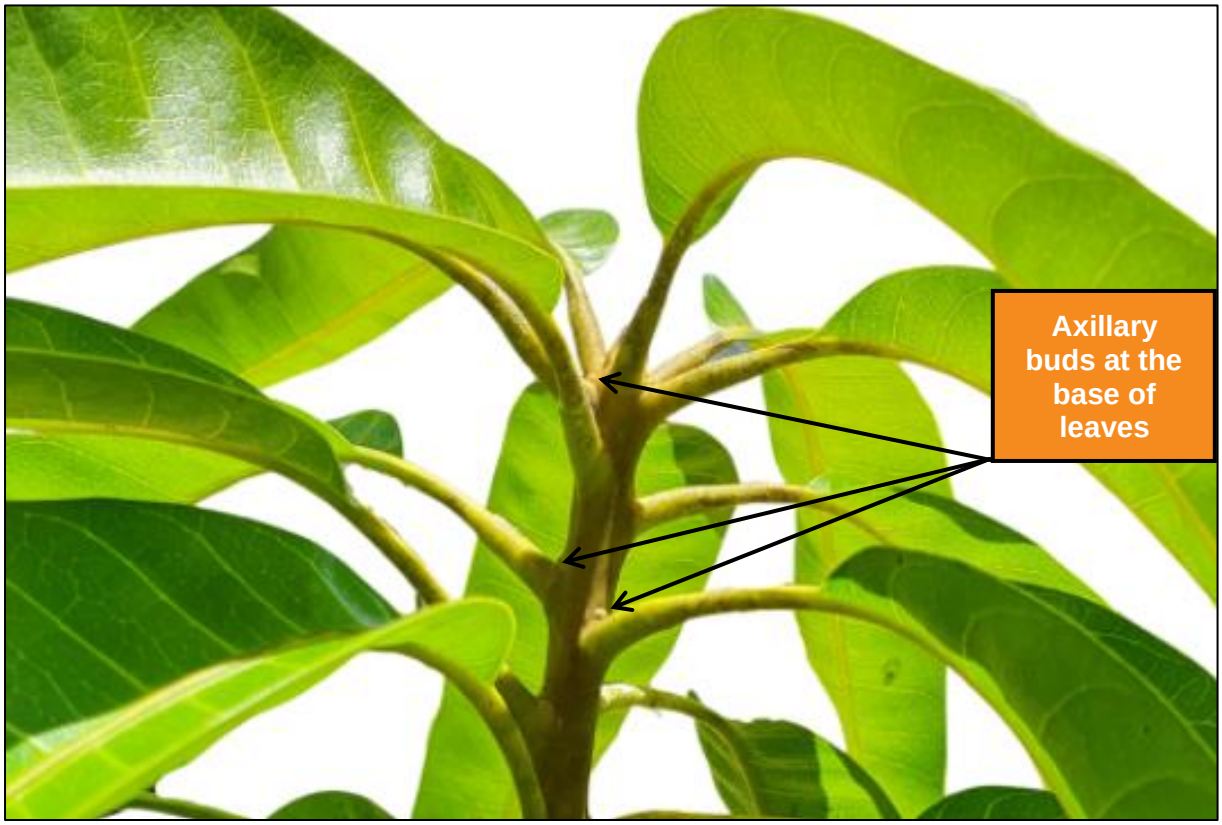
When to prune

Start pruning young trees as soon as they are established, normally six to eight weeks after planting. Trees planted in late autumn or winter should not be pruned until spring growth starts. Young mango trees should be pruned every one to three flushes to maximise branching and fruiting terminals.

When tees reach bearing age, prune them each year to maintain size, thin out the canopy and remove dead wood. The main pruning is done after harvest.

The first prune

Allow the tree to grow to over one metre in height before performing the first prune, to bring the tree back to a height of 80-90cm. Ideally the first prune will be below a whorl of leaves, where there is a minimum of three or more leaves that are spaced out along the trunk. At the base of each leaf are axillary buds. Pruning here will stimulate the buds to form shoots, resulting in a tree with branches that are well spaced around and up the trunk.



If there are no suitable options immediately below a whorl, trees may be pruned immediately above a whorl. However, this will result in multiple (up to seven or more) branches initiating from the same point that could become a weak branch junction prone to breaking in strong winds. The benefit of pruning immediately above a whorl of leaves is that it will provide multiple options for selecting branches.

The second prune

Allow the shoots that have developed from the axillary buds to produce at least two mature flushes. The branches should be pencil-thick or thicker (preferably) and the leaves should be dark green. Select three or four well-spaced shoots to become the main branches. Prune at roughly 60-80cm from the main trunk or roughly 1½ growth units, ensuring the cut is below a whorl of leaves as per the first prune. Remove all other shoots.

Subsequent pruning

New shoots will grow from the pruned side shoots. Select two or three of these shoots and repeat the pruning process as per the second prune. Remove all other shoots. Continue pruning in this way until the desired framework is obtained or until flowering.

Control fruiting for the first two or three years

Do not allow the tree to produce fruit for the first two to three years, depending on tree development, tree spacing and variety. For example, for heavy bearing varieties such as Keitt it is worth considering delaying first bearing until year three. Trees planted at higher density (e.g. 2 – 3 metres between trees in the row) will reach their desired canopy dimensions quicker than lower density plantings, meaning trees grown at higher densities can be allowed to bear earlier. If undesirable flowering does occur, allow the tree to set small fruit (roughly marble sized) before cutting the flowers off at the base. If flower panicles are removed too early, the tree may re-flower. Removing flowers will promote further vegetative growth.

Key references

Department of Primary Industries and Fisheries (1999) Mango Information Kit. Agrilink, your growing guide to better farming guide. Eds. Kernot I, Meurant, N., Holmes, R., MacLeod, N., Fullelove, G. and Bally, I. Manual. Agrilink Series QAL9903. Department of Primary Industries, Queensland Horticulture Institute, Brisbane, Queensland.

Devonport, T. L. (2006). Pruning strategies to maximize tropical mango production from the time of planting to restoration of old orchards. *Horticultural Science, 41*(3), 544-548

Oosthuyse, S. A. (1995). Pruning of mango trees: An update. *South African Mango Growers' Association Yearbook,* 15, 8pp.

Poffley, M., & Owen, G., (2006). Agnote D15: Mango pruning in the Top End. Department of Primary Industry, Fisheries and Mines, Northern Territory Government, Darwin, Northern Territory.

Wolstenholme, B. N., & Whiley, A. W., (1995). Ecophysiology of the mango tree as a basis for pre-harvest management. *South African Mango Growers' Association Yearbook*, 15, 10-17

Trellis design and construction

Trellis materials

Trellises consist of a system of supporting posts and wires, held tight by end assemblies (Figure 1). Most tropical tree crops are expected to have a lifetime of 20+ years, hence the trellises that support them need to be designed and constructed to last just as long.

In cyclone prone environments trellises should be strong enough to withstand cyclonic winds and support the estimated crop load. If you are considering installing trellising in a cyclone prone area it is recommended to consult the AgriFutures report 'Improving the Capacity of Primary Industries to Withstand Cyclonic Winds' available on the AgriFutures website, as this report contains detailed recommendations on trellis strength requirements and design & construction considerations for these areas (Drinnan et al., 2018).

Figure 1. Espalier trellis mango trees, part of the Planting Systems Trial at DAF Walkamin Research Facility. These trees were planted in 2013 at a spacing of 4m between rows and 2m between trees.

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Posts

Material

Various materials can be used, such as timber, concrete or steel; however, treated pine posts are best for strength, durability, price and workability. Treated pine posts such as CCA (copper, chrome, arsenic) are ideal as they are resistant to the harsh environment where most mangoes are grown. For organic growers, alkaline copper quaternary (ACQ) treated posts may be a more suitable option. The Planting Systems Trial at Walkamin Research Facility on the Atherton Tablelands, Queensland, used H4 CCA treated 150 mm diameter posts. It is recommended to over-engineer trellis infrastructure to ensure durability for the estimated lifetime of the orchard.

Depth

Ideally, posts should be installed at least ⅓ of their height. "The force a post can resist without moving is equal to the square of its depth; therefore the depth of the posts is critical" (Drinnan et al., 2018 p52). Soil type also influences resistance so sandier soils will require deeper placement and larger diameter posts than clay soils. Preferably posts should be rammed into undisturbed soil, as this provides improved stability, over posts that have been installed in augured and backfilled holes.

Orientation

Generally, trellises are installed in a north-south orientation to ensure the largest tree surface – the fruit wall – intercepts the most amount of sunlight possible. Site and locality characteristics should also be considered, including the slope, prevailing wind direction, shape of the block and sunlight intensity and duration. This may require the orientation to be adjusted from strictly north-south. Orchards in areas with high sunlight intensity should consider the potential implications of excess or extreme sunlight leading to sunburnt fruit and adjust row direction accordingly.

Height

The rule of thumb is that the height of trellises should be 67 – 83% the width of the rows, to maximise sunlight interception and avoid shading. It is recommended to consider management operations when deciding on final tree height as taller trellises must be stronger to support larger crop loads and are more difficult to prune, train, spray and harvest. Workers may need to utilise ladders or elevating work platforms to access the top-most wires which brings with it WHS concerns. Shorter trellises enable closer row spacing but this may require specialised farm machinery and/or a greater capital outlay per unit area. The Planting Systems Trial at the DAF Walkamin Research Facility used 4.5m posts with 1.6m below ground and 3.2m above ground, six wires spaced every 0.5m, beginning at 0.5m

above ground and the top wire at 3m. The dripper irrigation lines were fitted to the bottom-most wire. The inter-rows are 4m wide making the 3m finished height of the trees 75% the width of the rows. Ladders and elevating work platforms were necessary to undertake canopy management such as branch training and pruning on the top two wires and short picking poles were also required to reach fruit at harvest.

Wires

It is recommended to use 2.65mm diameter high tensile galvanised wire e.g., LifeWire. Larger diameter wires can be used e.g., 3.15mm, for added strength, however, this would increase costs. The number of wires is dependent on individual trellis design. The Walkamin trial is a 6-wire trellis with wires at 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0m above ground level (Figure 3). In recent trials the bottom wire has been positioned higher (eg 70-90cm from ground) to improve spray access and reduce fruit damage. Also the distance between wires was increased to 60cm. This resulted in a 5-wire trellis with wires at 0.7, 1.3, 1.9, 2.5 and 3.1m.

Attachment

Attach wires to posts with long-life, galvanised, barbed “U” nails e.g., 40mm x 4mm. Ensure the “U” nail is installed slightly off vertical to the post wood grain to reduce the potential of splitting. Do not pre-drill holes for “U” nails, to ensure a firm fit. Trellis wires should be attached to the end assembly post, not the screw anchor.

Trellis End Assembly

Anchored post

The end assembly supports the tension and load placed on the trellis by the crop and wind. It is therefore critical to ensure that end assemblies are correctly installed and strong enough to support this load. Where anchored end assemblies are used in temperate industries such as viticulture, the recommendation is for end posts to be positioned at an angle of 65° to ensure the force placed upon it by the trellis wires acts to force the post into the ground (Figure 2). However, this may be difficult to achieve in a mango orchard, particularly where taller trellises may be desired, requiring longer, wider posts to support the weight of mango trees. The system installed at the Walkamin Research Facility consists of 4.8m posts with 150mm diameter erected upright at 90° with the top guide wire at a 45° angle to the screw anchors (Figure 3). The screw anchor must be positioned into undisturbed soil.

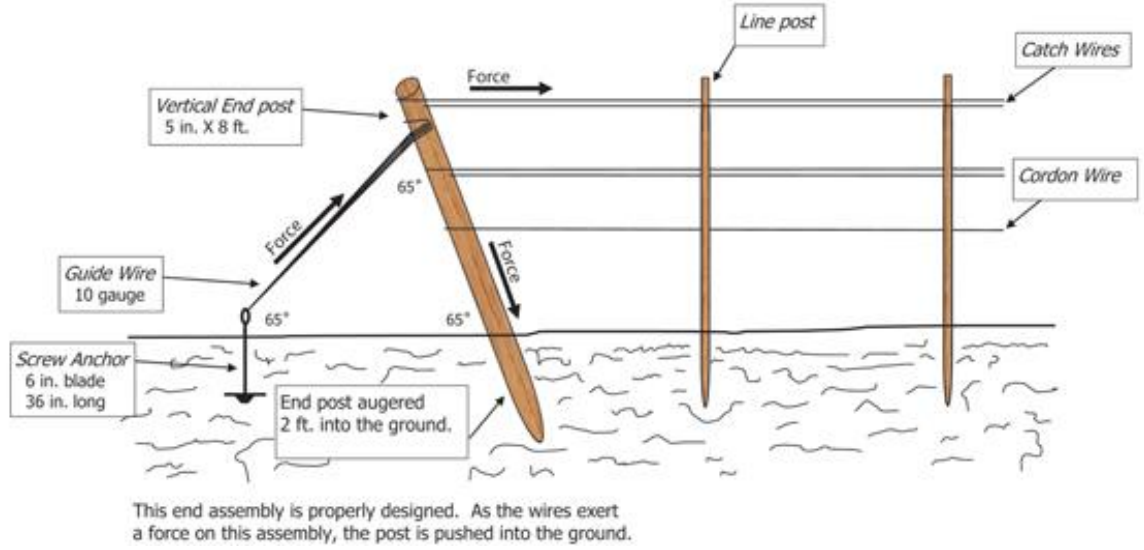

Figure 2. Trellis end post at 65° angle as used in temperate industries
(Source: https://aces.nmsu.edu/pubs/_h/H331/).

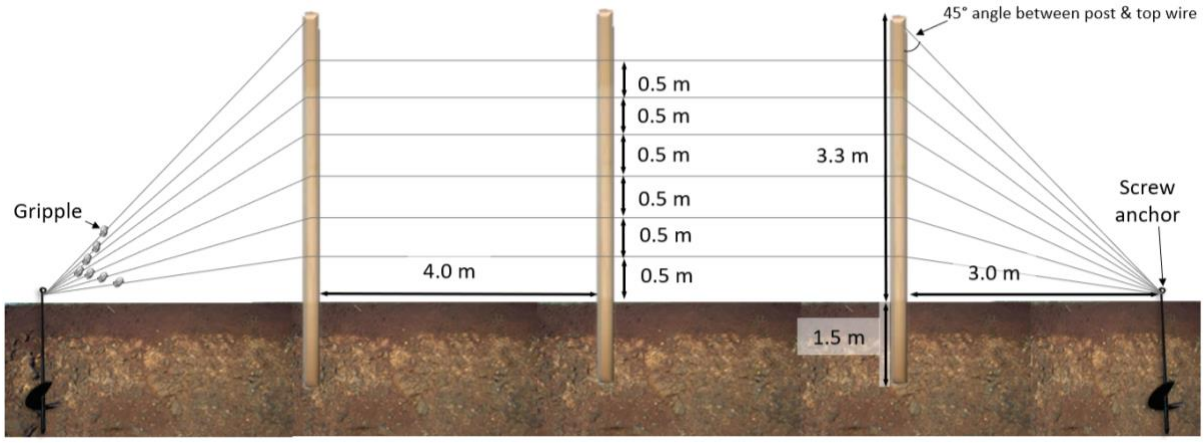

Figure 3. Trellis assembly at 90° angle as used in mango planting systems trial at Walkamin Research Facility.

Trellis End Assembly

The costs for trellising were calculated for a hypothetical 1-hectare block (Table 1). The block specifications were:

1. 18 rows x 138m long, 66 trees/row
2. 4m inter-rows and 2m between trees = 1,188 trees/hectare

3. 3m tall fence-style trellises with 6 x wires per trellis spaced 0.5m apart; starting at 0.5m from the ground

Table 1. Costs of materials and labour for one hectare of trellis infrastructure.

Item	Quantity per row	Quantity per ha (18 rows)	Cost ($)	Sub-Total ($)
175mm x 4.8m CCA H5 Pine logs	12	216	98.50	21,276
2.65mm long life, grow wire (m) 140m x 6 wires (per m)	840	15,120	0.17	2,517
1360 long single plate 20mm high tensile rod anchor	2	36	30.45	1,096
40mm x 4mm long-life galvanised, barbed staples (6/post)	72	1296	0.08	103
Medium gripple plus 2-3.25mm	12	216	2.60	561
Post installation (machinery and labour per hr)	1	18	195.00	3,510
Wire installation (labour per hr)	6	18	25.00	2,700
			TOTAL	**31,763**

Note: Prices are a guide only and were current as of January 2020.

(a) (b) (c)

Figure 4. Materials for trellis construction (a) gripples for attaching wires, (b) wire spinner and (c) example of screw anchor.

Key references

Drinnan, J., Wiltshire, N., Diczbalis, Y., Holden, P., and Thompson, M. (2018). Improving the capacity of primary industries to withstand cyclonic winds. AgriFutures Australia, New South Wales.

Trellis pruning and training

What is tree training?

Tree training sets up the tree structure by pruning or bending limbs into position.

- Pruning trims or cuts branches or stems to encourage growth and removes dead, dying, and diseased branches or spent terminals
- Bending is the process of positioning branches and securing (tying) them in a horizontal or angled position.

Why do it?

Tree training develops a strong tree structure, slows growth, reduces vigour and helps bring a young tree into production earlier.

Types of training systems

The espalier system (Figure 1) is the most commonly used mango trellis training system and trains branches horizontally along the wires (a & b). This system is the simplest and easiest design to implement. Training branches horizontally along the wires is also a very successful method to reduce branch vigour. The palmette system (Figure 1, c & d), trains branches to follow the natural growing habit of the tree into a fan or palm shape that fills in the trellis. A benefit of the palmette system, is that it is similar to natural tree growth, and may more rapidly fill the trellis structure. Problems with this system include the semi-vertical branch training does not restrict branch vigour as well as horizontal training and that the diagonal natural tree growth can be difficult to train onto trellis wires and enable pruning to create regular secondary and tertiary branch whorls.

(a)

(b)

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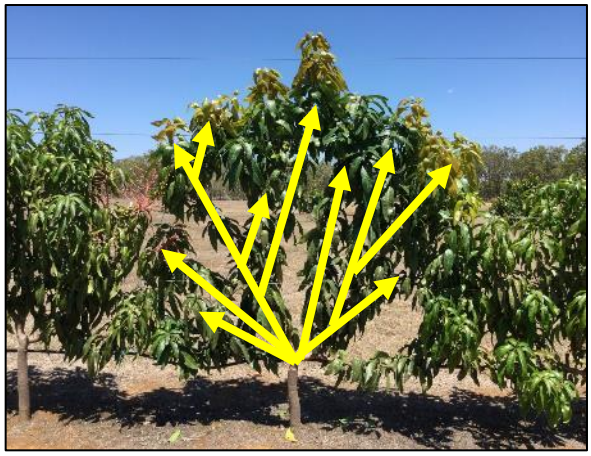
(c)



(d)

Figure 1. Trellis training systems – a & b espalier; c & d palmette

Pruning for trellis designs: Espalier training system

Mango trees grown using the espalier trellis method consist of a primary central leader branch that is trained vertically towards the top wire. Secondary lateral branches are trained horizontally along the wires of the trellis and attached with rubber ties or baling twine. The secondary lateral branches are pruned every 15 to 30cm to produce tertiary branches (Figure 2). For maximum productivity, it is critical to develop numerous tertiary branches along the secondary lateral branches, as these are the sites where flowering and fruiting occurs (Figure 2).

For a video on how to prune and train espaliered mango trees please view the High-density mango orchards: espalier trellis video on the Queensland Agriculture YouTube channel.

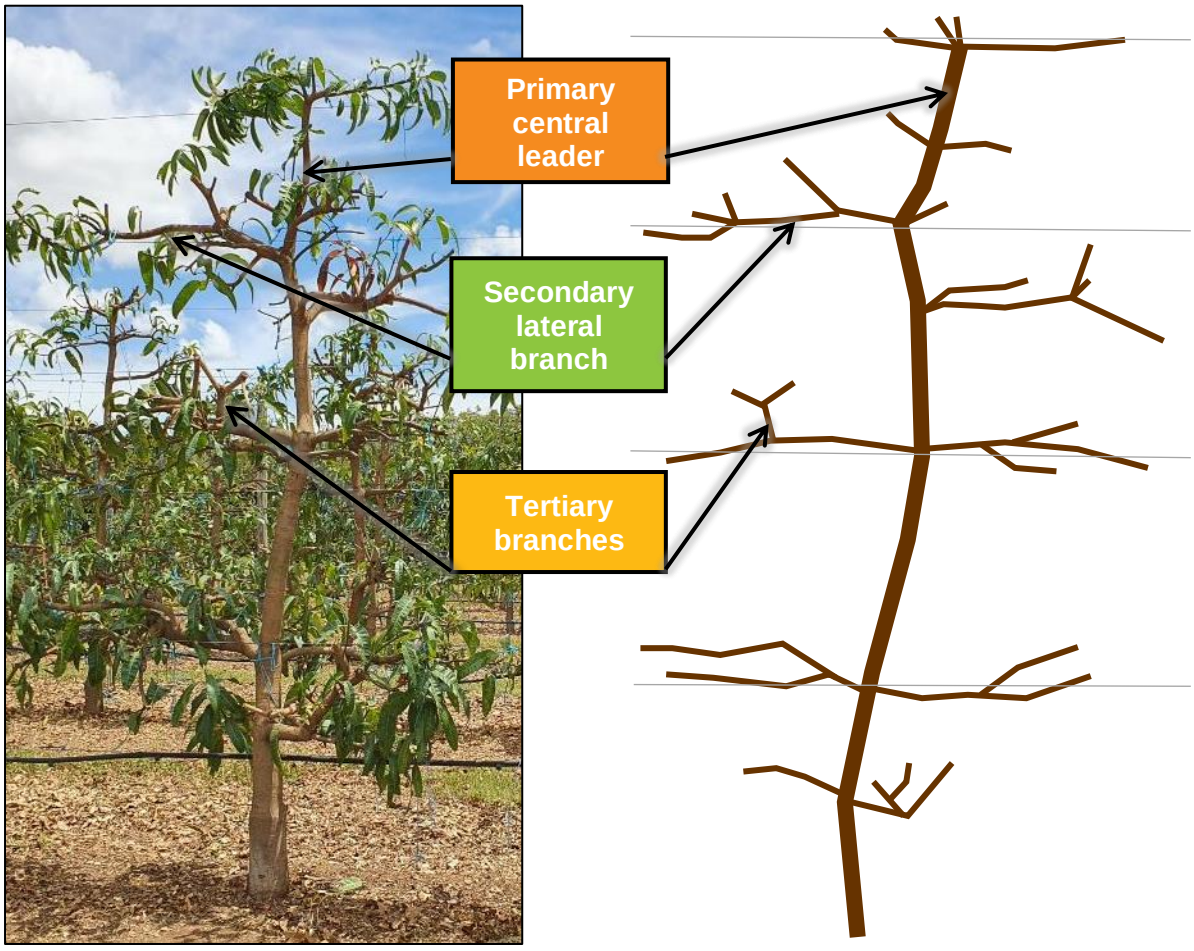


Figure 2. Espaliered mango trees consist of a central leader grown from the ground to the top wire; secondary lateral branches grown along the wires and tertiary branches that emanate from the secondary lateral branches and produce flowers and fruit.

Equipment required

To prune and train espaliered mango trees you will need:

- A good pair of secateurs
- Rubber ties for securing branches to wires (Figure 3a). Rubber ties stretch which reduces the risk of constricting branch growth
- Baling twine or similar for branch training tasks where rubber ties are unsuitable (Figure 3b)
- Scissors or knife for cutting twine. Alternatively, secateurs can also be used
- A ladder. This will only be required once the trees have reached the higher trellis wires

(a) (b)

Figure 3a. Rubber ties are used to secure the tree branches to the wire;
Figure 3b. Where rubber ties are not long enough or unsuitable, baling twine may also be used.

First prune

The first prune should be above the first wire to ensure branching occurs above the wire, not below. The aim is to always bend limbs down to a wire, not up, as bending branches reduces vigour. Pruning above the wire ensures branches are bent towards to the wire. Ideally the first prune will be above the wire and below a whorl of leaves, where there is a minimum of three or more evenly spaced axillary buds present. Pruning here will stimulate the buds to form branches that will become the single leader and lateral branches (Figure 4).

If there are no suitable options immediately below a whorl, trees may be pruned immediately above a whorl. This will result in multiple branches initiating from the same point which could become a weak junction. However, it will provide multiple options for selecting the laterals and central leader. The main aim is for the first prune to be **above** the first wire. Remove any shoots that develop below the first wire and below the graft union (Figure 5).

Figure 4. It is best to wait for the tree to grow above the first wire before completing the first prune. Once there are three or more evenly spaced leaves above the first wire, prune above the topmost leaf, ensuring the axillary bud is retained. Avoid pruning immediately above a whorl of leaves or below the wire.

Figure 5. Remove branches that grow below the first wire or below the graft.

The first limb training

The first limb training should be completed after flush has matured. Young flush is delicate and can easily snap, so it is important to wait until flush is fully developed. Select the most vigorous branch to be the central leader, preferably a branch that emanates from the middle of the tree (c). The central leader can be left free growing if it is growing vertically towards the second wire, or baling twine can be used to encourage upright growth (d).

(c)

(d)

Select one to two branches on each side of the central leader to become the secondary lateral branches. Attach these to the wire using rubber ties or baling twine (e). The key to remember is not to tie the branches too tight. The plant is *encouraged* to grow along the wire; not *forced*. Tying it back too tightly only restricts movement and growth and can cut into the branches. If there are two lateral branches on each side, tip one lateral branch at 15 cm and the second branch at 30 cm to produce the tertiary branches on each side of the central leader. If there is only one secondary lateral branch on each side, tip each at 15 cm (f). If there are more than four branches, thin branches back to four branches by removing water shoots and vertically growing shoots, retaining downward or outward facing branches where possible.

(e)

(f)

The second and subsequent limb training

Once the lateral branches have produced shoots and they have hardened off, choose one to continue along the wire as the lateral and tip-prune the remaining branches to form the tertiary branches. As with the first limb training, remove water shoots and vertically growing shoots. The preference is for downward or outward facing tertiary shoots as these will produce the tertiary branches that produce the flowers and fruit. Upright branches can become dominant if not removed. This can starve the secondary branches which in turn provides fewer resources to the tertiary fruiting wood.

After the second growth flush has matured, again select one branch to continue along the wire, prune it at 15-20cm and tip-prune the remaining branches to form the tertiary branches. Pruning in this way will result in tertiary branches evenly spaced along the secondary branches giving rise to well-spaced fruiting terminals along the entire wire. Mangoes are terminal bearers, meaning they only produce flowers and fruits at the ends of their branches. If the secondary branches are not tip-pruned frequently along the wire but are instead left unpruned to elongate along the wire, the likely outcome is fruit bearing occurring only at the end of each branch.

When the primary central leader has grown above the second wire, prune again to produce lateral shoots and follow the same process as for the first wire. Both vertical and lateral pruning and training can be carried out at the same time. i.e., it is not necessary to wait until the tree has filled out the first wire, before undertaking pruning and training at the second wire.

Annual maintenance

After harvest, prune tertiary branches back to the first or second growth flush from the lateral branch. In older systems, a hedging machine can be used first, to remove most of the biomass, however hand pruning will still be required to complete the pruning process.

Inspect ties and baling twine regularly to ensure they are not restricting plant growth or cutting into branches and remove any that are no longer required. If in good condition, rubber ties can be reused.

Pruning and training once tree shape established (5+ years)

After the trees are mature and all laterals and sub-laterals have been established, pruning is required twice per year – once, after harvest to bring branches back to the sub-laterals and remove water shoots (Figure 6) and once after flowering and fruit set to remove unfruitful branches and control excessive vegetative growth. Avoid removing too much foliage close to harvest as this can cause sunburn on the fruit (Drinnan *et al.*, 2018).

Figure 6. Mature espaliered mango trees should be pruned back to the first or second growth flush immediately after harvest.

Limb training: when to do it?

Pruning encourages a heavy vegetative response and should be conducted regularly over the first five years to develop the desired branching structure, as quickly as possible. If pruning is not conducted regularly then a lot of vegetative growth may be removed (and wasted) when cutting branches back to achieve the desired 15-20cm branch length. Avoid training branches before flush has hardened off, as the developing stems and branches are fragile and prone to breaking.

Training fundamentals

Lateral branches should be kept smaller than the leader. The main branch can become starved if the subsequent branches become too dominant or vigorous. A good rule of thumb is that laterals and sub-laterals should be no larger than ½ to ⅓ the diameter of the branch from which it originates. Leave companion branches to replace dominant branches over time with ones that are less vigorous. Gravity will assist with maintaining horizontal branches over time, especially once trees start to flower and fruit.

Remember to check rubber ties and strings regularly to ensure they are not cutting into developing branches (pictured). Remove or replace ties before they cause damage, as this can provide entry points for disease.

Key references

Drinnan, J., Wiltshire, N., Diczbalis, Y., Holden, P., and Thompson, M. (2018). Improving the capacity of primary industries to withstand cyclonic winds. AgriFutures Australia, New South Wales.

Trellis vs. Hedge designs

Once the decision has been made to transition to a higher density planting, the next choice to consider is whether to opt for a hedged design (Figure 1) or install a trellis system (Figure 2). Both systems have advantages and disadvantages that growers should consider prior to finalising their decision. Table 1 outlines the advantages and disadvantages of trellis designs and Table 2 summarises the advantages and disadvantages of high density slim-hedge designs.

Figure 1

Figure 2

Table 1. Advantages and disadvantages of trellis designs

Advantages	Disadvantages
Provides strength and support to developing tree and resilience to cyclones and/or strong winds	Trellis infrastructure requires a significant initial capital investment
Narrow canopy allows greater light and spray penetration improving fruit quality, quantity, and blush	Trellis infrastructure may require maintenance and/or replacement over time
Fruit wall allows for quick and easy harvesting, reducing labour costs	Installing trellis infrastructure requires specialised skills and equipment
Facilitates higher planting densities per unit area; orchards begin producing commercial yields earlier	Specialist skills required to train and prune branches to desired trellis shape
Encourages tree to petition more resources towards fruit production in preference to vegetative growth; improved yield	High labour costs for training, bending and pruning branches until mature tree architecture is established; this can be 10+ years
Enables mechanisation of harvesting and automation of yield estimation	New technology with no long-term studies of trellis longevity and/or ongoing maintenance costs of aging infrastructure

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Table 2. Advantages and disadvantages of slim-hedge designs

Advantages	Disadvantages
Significantly lower initial capital investment costs as no trellis materials or installation costs required.	More prone to canopy gaps, as there is not any wire infrastructure onto which branches can be trained accurately
Quick and efficient hedging with mechanical hedger; significantly reduced pruning costs	Not as adaptable to mechanised harvesting; particularly with some fruit hanging inside canopy.
Low maintenance costs	Fruit hanging inside canopy likely to have higher pest pressure, lower blush and more skin blemishes.
Low complexity of management, particularly for specialist pruning and training skills	Yield forecasting less accurate as fruit hanging internally may be occluded from view
	Lower resilience to strong winds and/or cyclones

Resin Canal Discolouration in Mangoes

Overview

Resin Canal Discolouration (RCD) is a fruit quality defect that reduces the marketability and profitability of mango fruit in the Australian domestic market. It has been an issue in the Australian mango industry for many years. Market reports of RCD have increased recently, particularly for Kensington Pride (KP) fruit produced in the Northern Territory (NT).

Symptoms of RCD

RCD displays as browning of the resin canals in mango fruit. It appears as red-brown streaks that form networks through the flesh and irregular brown mottling across the peel. It occurs sporadically and has been observed at all stages along the supply chain from field harvest to retail. Symptoms become more obvious during ripening, with severity steadily increasing as fruit develops from firm-ripe to eating-ripe.

Figure 1. RCD symptoms in mango fruit, noting the streaks through the flesh and discolouration on the skin.

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Researchers have found that:

☑ RCD can be found in green and ripe fruit

☑ RCD symptoms present in individual fruit increases as the fruit matures

☑ RCD is sometimes, but not always, visible on the surface (it can be in the flesh without showing on the surface)

Fruit physiology- resin canals and mango sap

Resin canals are flesh-coloured ducts that run through the flesh of mangoes. They store sap under pressure. They also act as part of the plant's defences against insects (such as fruit flies trying to lay eggs on fruit).

There are several reports on the role of canals and sap in the defences against fruit flies. Some found that sap pressure forced the fruit fly eggs out of the fruit when they were laid into resin ducts. There are also suggestions that the sap and resin compounds may be toxic to fruit fly eggs and larvae.

Mango sap typically contains the enzymes *polyphenol oxidase* (PPO) and *peroxidase* (POD). Both of these enzymes can cause sap burn on the outside of the fruit, they are also linked to the brown discolouration seen in RCD. As with sap burn, these enzymes need an external factor to trigger a reaction and cause the browning effect.

Figure 2. Mango resin canals become darker when PPO and POD enzymes are triggered, resulting in resin canal discolouration (RCD).

There are varietal differences in the patterns of size and distribution of canals as well as differing sap strength. For instance, a 2017 study found that Tommy Atkins and Ataulfo varieties had a greater density of resin canals in their fruit than the Criollo and Manila varieties. This is most likely the reason that some mango varieties express RCD more than others.

Factors in the development of RCD

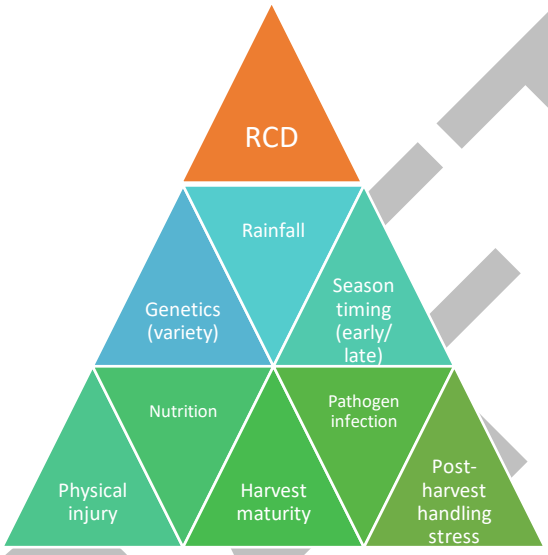


Figure 3. Factors implicated in RCD expression.

There is significant evidence that both the environment and management practices can influence the rates present in fruit.

Read more

Read about some of the past research trials on RCD in this slideshow by Andrew Macnish and Cameron McConchie (Queensland and Northern Territory Governments)

Although there are still a lot of gaps in our understanding, grower surveys and trials have shown that:

☑ RCD can vary between farms and harvest dates.

☑ RCD is more frequently found in fruit that have been through commercial supply chains.

☑ RCD is more frequently found in KP and some of the Asian mango varieties.

☑ RCD is more frequently found in fruit picked early (immature).

☑ RCD is more frequently found in fruit picked within 12 hours of rain.

☑ RCD is frequently found in association with bacteria.

Biological factors

Preliminary studies from Queensland, Northern Territory and Tasmania have looked into potential biological causes. Several studies have isolated bacteria *(Enterobacter* and *Pantoea agglomerans*) from fruit with RCD symptoms. The same bacteria were also isolated from mango wash and water dump solutions at NT mango farms and packing sheds.

Unfortunately, while the research suggests there is a link, it is not clear cut. When exposed to solutions with the bacteria, KP mangoes have a greater tendency to develop RCD, but not under all conditions.

Nutritional factors

Fruit from orchards with persistent RCD issues have been found to have higher variations in the ratios of calcium to potassium (Ca:K) and calcium to iron (Ca:Fe) ratios than those fruit without RCD. This study determined a distinct separation of nutrient content between mango fruit from RCD+ and RCD- orchards. It is not yet clear whether the nutritional in-balance causes RCD or is a result of RCD.

Read more

Read about the importance and function of calcium in mango fruit on the AMIA website.

Potential management strategies

Nutrition

Annual leaf and soil analysis enables growers to make informed decisions about nutrient application. Monitor your plant calcium by leaf analysis, soil calcium and soil pH analysis annually. Optimum (leaf) calcium levels are 2.0- 3.5% in acid soils and 3.0– 5.0% in alkaline soils.

It is critical for calcium to be available to the plant in the first 6-10 weeks of fruit development. Foliar sprays of calcium products targeting young developing fruit have little or no effect on calcium levels as the majority is taken up by new roots. Time your applications to that of root flushes.

Avoid over application as calcium competes with other nutrients (magnesium (Mg), zinc (Zn), boron (B), copper (Cu) and phosphorus (P)) for uptake, and cause deficiencies in these nutrients.

Harvest timing

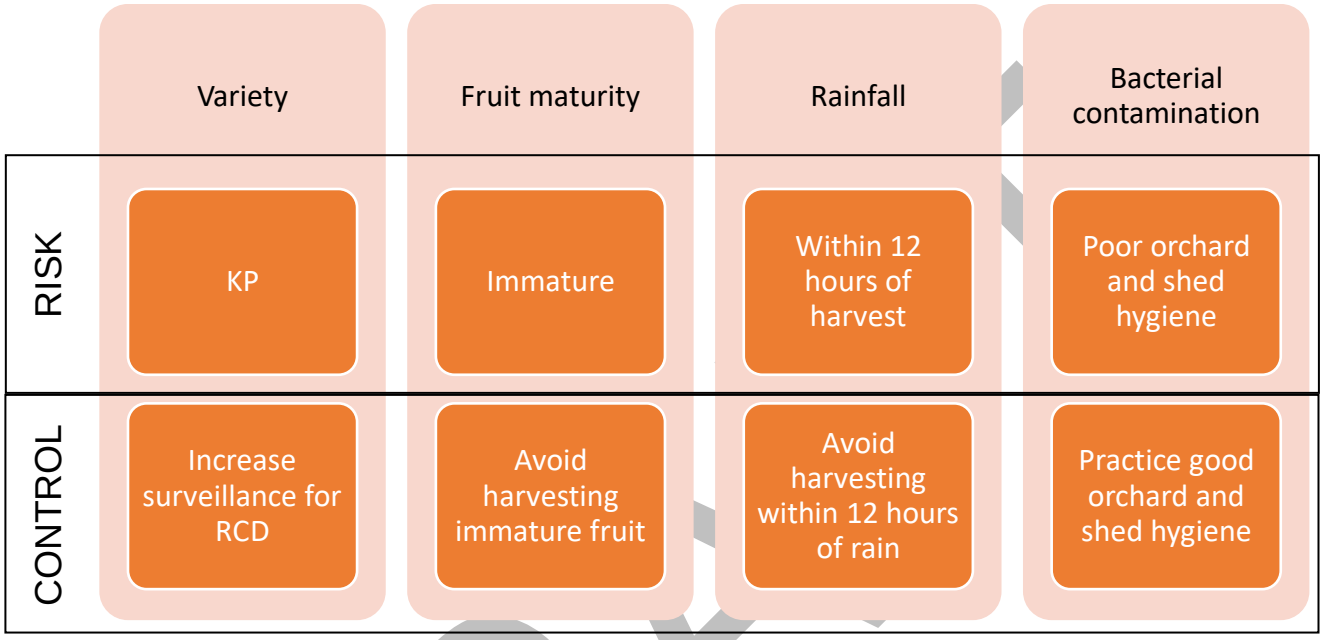


Figure 4. Simple decision matrix to reduce the risk of RCD

There are some simple harvest controls to reduce the chance of RCD in your fruit. If you have a KP orchard increase your surveillance and keep records of when you get RCD symptoms. Fruit harvested within 12 hours of a rain event, is more likely to develop RCD, so avoid picking during these windows.

Immature fruit is more likely to have RCD, if you have a susceptible variety avoid picking immature fruit where possible, particularly if there are other compounding factors (recent rain or a block known to have high levels of RCD in the past).

Post-harvest handling

☑ RCD is more frequently found in fruit with Stem End Rot.

☑ RCD is less frequently found in fruit that have been through a post-harvest hot water treatment at 52˚C

☑ RCD is more frequently found in fruit stored at 30˚C than 20˚C

RCD is found more frequently in fruit that are exposed to commercial harvest, pack house, and distribution procedures, compared to fruit ripened on the tree. This indicates that industry practices may aggravate the condition and suggests that orchard and shed hygiene could play a large role in reducing RCD. The cool chain is important, ensure that fruit is pre-cooled and transported at the appropriate temperatures.

Bacterial contamination in mango fruit can occur at any stage throughout production and supply chain process, the inclusion of an effective postharvest sanitisation step may offer a potential strategy for managing RCD. Research is ongoing on the potential for sanitisers to reduce the rate of RCD in mangoes.

Trials in Queensland found a hot water treatment at 52˚C for 5 minutes reduced the amount of fruit with RCD, but it did not eliminate it altogether.

Summary

There are currently no known controls to eliminate RCD in mango fruit however there are some steps which can reduce the likelihood including harvesting at the correct maturity, avoiding harvest within 12 hours of rain, improved orchard and shed hygiene and maintaining cool chain temperatures.

Key references

Asis, C.A., Meschiari, L. and McConchie, C. (2019). Ionome balance analysis of mango fruit from orchard with and without resin canal discolouration. Acta Hortic. **1244**, 221-228

Macnish, A., McConchie, C., Hofman, P., Joyce, D.C., T., 2014. Towards identifying factors that contribute to mango resin canal discolouration. Mango Matters **14**, 9-12.

Marques, J., Hofman, P., Macnish, A., 2016. Postharvest handling practices and irradiation increase lenticel discolouration in 'B74' mango fruit. The Journal of Horticultural Science and Biotechnology, **1-7**.

Macnish, A.J., Hofman, P.J., Mcconchie, C., & Campbell, T. (2014). Identifying factors that contribute to mango resin canal discolouration. Hort Innovation report.

San, A.T. (2017). Lenticel discolouration, under-skin browning and resin canal disorder in Australian mango fruit cultivars. PhD Thesis, School of Agriculture and Food Sciences, The University of Queensland

Guillén L, Adaime R, Birke A, Velázquez O, Angeles G, Ortega F, Ruíz E, Aluja M. (2017) Effect of Resin Ducts and Sap Content on Infestation and Development of Immature Stages of Anastrepha obliqua and Anastrepha ludens (Diptera: Tephritidae) in Four Mango (Sapindales: Anacardiaceae) Cultivars. J Econ Entomol. **110 (2)**, 719-730

Mango harvest timing

Mangoes are a perishable product with a short harvest window and a reasonably short shelf life. Understanding when to harvest fruit is important at both the farm and industry level. There are a number of different ways to predict harvest timing, spanning from the most basic flesh colour cards to the latest range of technology in robotics and machine vision.

What is harvest maturity

In Australia, mangoes are trucked from the northern tropical regions of Queensland and the Northern Territory, from Western Australia and a from a small part of New South Wales to the markets in the major capital cities. The distances travelled between farm and market can be vast, for example Darwin is approximately 4,000km from Sydney by road. Due to the distance from market, mangoes are picked at a mature green stage. They are then ripened either in transit or upon arrival in the southern markets.

Read more

Read more about mango ripening options in this information sheet from the Queensland Government and Hort Innovation.

Fruit physiology and changes during ripening

If you consider the experience of eating a ripe mango, many different aspects come in to play, i.e., flavour, aroma, texture, sweetness, etc. Each of these aspects is determined by the biochemical and physical attributes of the fruit and they change from an unripe to a ripe fruit. Some of these changes are linked and others are independent.

This project 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.

These resources have been created under the strategic levy investment project Building Best Management Practice Capacity for the Australian Mango Industry (MG17000), part of the Hort Innovation Mango Fund.

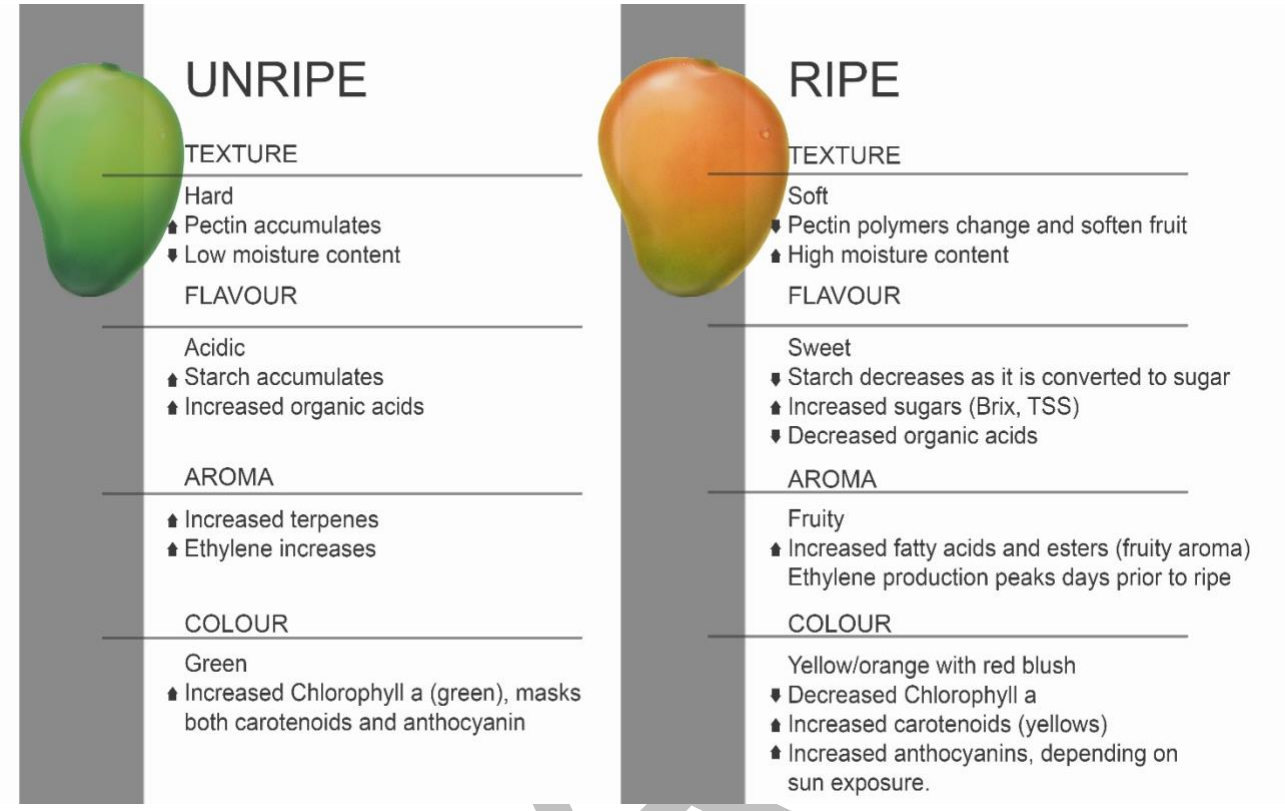


Figure 1: Some of the critical differences in ripe and unripe mango fruit contributing to texture, flavour, aroma and colour. (Note: TSS = Total Soluble Solids).

Picking mangoes at the correct maturity ensures the end quality is consistent with market standards. It helps the fruit better withstand lower travel temperatures, and reduces the risk of defects such as low sugar levels, excessive shrinkage, blotchy green skin, and resin canal discolouration (RCD).

Tools to determine when to pick

There are a number of ways to determine fruit maturity, each has their own advantages and disadvantages. It is recommended that at least two different methods be used for accurate prediction.

Dry matter

How it works

Dry matter is a measure of the percentage of solids versus water in the fruit and as such includes the starch and sugars combined. In Kensington Pride (KP) fruit there is around 80% correlation between dry matter and Brix.

In Australian mangoes, the dry matter changes over time from 11% at stone hardening to 22% at fully mature, rising by around 0.72% per week.

Fruit thinning and manipulation of irrigation can both influence the dry matter content of mango fruit.

What is "maturity" defined as
Dry matter maturity varies slightly between varieties, in general a 14 - 16% dry matter is considered mature enough to pick and ripen with flavour.

See more

Find out more about dry matter with this video from the Northern Territory Government.

Read more

Read more about dry matter with this information sheet from the Northern Territory Government.

Heat sums

How it works
Heat sums or heat units are used in a number of crops to predict harvest timing. They are a non-destructive measure based on flowering timing within an orchard.

Certain aspects of plant growth are influenced by temperature, where development or growth only occurs within a certain optimal temperature range. Heat sums are a measure of the relationship between accumulated heat over time and the corresponding growth. They are used in many crops to predict harvest timing, including maize, cotton and mangoes. It is essentially a calculation, which cumulatively adds the daily average temperatures within the optimal growth range until a pivotal sum of heat units is reached. For mangoes, temperatures under 12˚C are considered to be outside the optimal range, so the formula is represented as:

$$Daily\ heat\ unit = \left[\frac{(\text{daily max}\ temperature + daily\ \text{min}\ temperature)}{2}\right] - 12$$

Heat sums predict the timing of fruit maturity in an orchard or block given an initial flowering date. For KP and R2E2 fruit the flowering date is at stage 6 of panicle emergence, but for Honey Gold, the flowering date is when there is a full panicle of approximately 2/3 open flowers (stage 14). Some growers prefer to use stage 14 as it is easier to see when driving through an orchard. In this case, there are approximately 300 heat units of difference between stages 6 and 14.

Stage 6

Stage 14

Figure 2: Mango flower development progresses though a number of documented stages. Stage 6 and stage 14 correspond with the date flowering is measured for heat sum calculations.

See more

Find out more about calculating mango heat sums with this video from the Northern Territory Government.

What is "maturity" defined as

Heat sum based maturity forecasts are based on historical average temperatures, which are updated with real temperatures as the season progresses. Different mango varieties have slightly different heat units as follows.

Table 1: varietal differences in heat units used to calculate maturity.

Variety	Heat unit
KP	1600
Calypso	1680
R2E2	1800
Honey Gold	1500
Florida types (Keitt, Kent, Tommy Atkins etc.)	1680

Near Infra-Red (NIR)

How it works

NIR spectroscopy is a non-invasive way to measure the internal flesh colour and determine sweetness (Brix). It is particularly useful in varieties such as Calypso, which has less obvious external signs of maturity.

It works by directing a beam of light of a known wavelength at the fruit. Variations in the concentrations of various compounds affect how much light the fruit absorbs and how much light is reflected back to the machine. The NIR gun measures the reflected light and uses a calibration model to determine what that corresponds to in terms of dry matter, brix and flesh colour. The model requires the NIR gun to be re-calibrated yearly as regional and environmental factors can influence these traits.

Felix Instruments produce a model that is calibrated for Australian mangoes; visit the Felix Instruments website for more information.

See more

Find out more about NIR with this YouTube video from Felix Instruments.

Fruit maps

Fruit maps uses an amalgamation of heat sums and mapping to provide harvest predictions at the orchard scale. The open access site calculates heat sums online using temperature loggers placed in major mango growing regions of Australia.

See more

Find out more about fruitmaps.com with this video from the Queensland Government.

Australian Tree Crop Map

A yield prediction tool currently being developed, the Australian Tree Crop Map has the ability to map commercial tree crops of avocado, banana, citrus, macadamia, olive and mango for natural disaster and biosecurity responses. The map was used in 2017 with Cyclone Debbie, and during and following the 2019/20 bushfires. All commercial mango orchards more than two hectares have been mapped.

See more

Find out more about the Australian Tree Crop Map with this video.

The map is currently being developed to predict mango yields across the Northern Territory and Queensland based on remote sensing as part of the Multi-scale monitoring tools for managing Australian tree crops – phase 2 project. Very high-resolution satellite imagery is captured over orchards in northern Australia, the satellite imagery is processed and analysed to predict potential yield. In trials the yield forecasts have achieved accuracies of around 90%, when compared to actual harvested data. Ideally, this function would be used in conjunction with a handheld NIR sensor and accompanied with an app mango so that growers will be able to optimise harvest timing.

Read more

The Hort Innovation webpage on multi-scale monitoring tools for managing Australian tree crops - phase 2 can be found online.

Machine vision forecasting

Machine vision uses robotics and heat sums to estimate flowering and fruit loads. A system of lights and cameras are attached to an ATV or ute and driven slowly through a mango block after dark to capture multiple images of the mango canopy, which enables shape/colour recognition software to identify, count and geo-locate individual flowers and fruit.

The flowering footage is analysed and converted into a harvest date prediction via heat sum calculations. Whilst footage from the stone hardening stage is used to forecast volumes, producing a report on the number of fruits in each block, yield variability and harvest time.

See more

Find out more about the machine vision project with this video from the Queensland Government.

Other measures

- Flesh colour cards have been available to allow growers to identify the internal flesh colour corresponding to “maturity”. This varies between mango varieties and should be used to confirm maturity rather than the sole determination of harvest timing.
- The Total Soluble Solids (TSS) or Brix is a measure of the sugars within a fruit. This is a destructive measurement using a refractometer to assess the TSS within the juice of the mango fruit.
- Skin colour guides are available on the Australian Mangoes website, which is not a reliable tool for identifying harvest maturity on its own. However, it has been used in the past by growers to confirm fruit development.

Summary

There are some general rules of thumb for mangoes to distinguish mature from immature green fruit, however these differ slightly between varieties e.g. KP, Calypso, R2E2 or Honey Gold. The table below summarises maturity indices.

Table 2: Summary of common maturity indices.

	Immature	**Mature green**	**Ripe**
Skin colour	Dark green	Light green (0-10% yellow)	Yellow / Orange • KP 70- 100% yellow • Honey Gold 90-100% • R2E2 50- 100% • Calypso 90- 100%
Internal flesh colour	Pale lemon colour	Yellow	Dark Yellow/ Orange
Shape	Shoulders and beak have **not** filled out	Shoulders and beak have filled out	Shoulders and beak have filled out
Firmness	Hard	Hard	Soft / firm soft
Dry matter	<14%	>14%	22
Brix		<14˚ Brix	14˚ Brix +
Heat sum units		• KP 1600 • Calypso, Florida types 1680 • R2E2 1800 • Honey Gold 1500	

Crop forecasting

Australian Mangoes runs a crop forecast every year. This is a logistics tool for the whole supply chain, predicting peaks and troughs to avoid shortfalls in harvest labour, refrigerated trucks, cool rooms at the interstate markets, and to plan marketing campaigns and events.

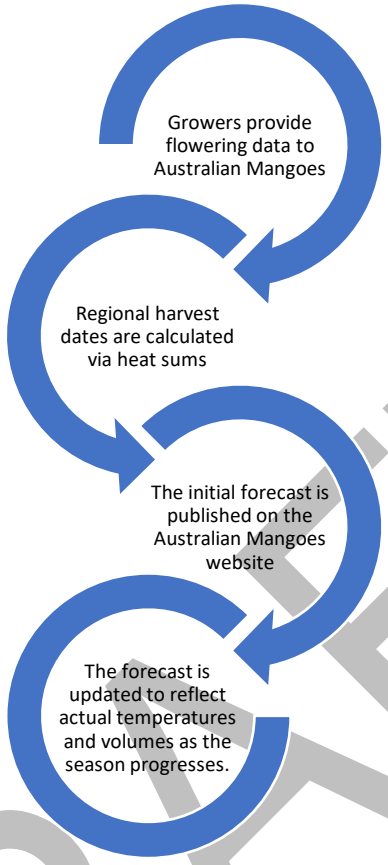
The Australian mango crop forecast has been running since 2006, and has been run by Australian Mangoes since 2014. It essentially models the heat sums from all of the participating orchards into a graph that identifies the start, peak(s) and tail of the season (no individual grower data is identified). It can show the potential overlaps between different regions (such as Darwin and Katherine) and estimates the timing and size of the peak.

Used well it can:

- Allow harvest labour companies to direct backpackers where and when to go to each region, and organise overseas workers in case of labour shortages.
- Allow growers to identify overlaps with other regions, which might cause labour or refrigerated trucking shortages, so they can plan accordingly.
- Allow other industries (such as the seafood and melon industries) to identify when they may overlap with the mango harvest and plan their refrigerated transport accordingly.
- Allow the organisation of ripening rooms and refrigerated space at the markets and distribution hubs.
- Allow the mango industry and major retailers to target marketing events and advertising for fresh Australian mangoes.

How it works

The forecast consists of data collected from growers and packhouses via a text message system. The initial forecast is calculated using heat sums and average historic temperature data, and then updated regularly throughout the season with actual temperature data and volumes. The forecast is published through Australian Mangoes's e-newsletter, My Mango.



Read more

Read more about the current Australian Mangoes crop forecast.

Summary

Predicting harvest timing is useful at the orchard, regional and national level. It allows growers and industry to organise the logistics of harvest labour, transportation, ripening rooms, marketing and events to maximise both quality and profitability.

There are a range of tools that can assist growers with defining harvest timing, which can be affected by seasonal, environmental and regional differences. For this reason, it is best to use two different methods to determine fruit maturity.

There are a range of emerging technologies associated with accurately identifying harvest timing and yield predictions, using a mix of the heat sum calculation, dry matter, flesh colour, remote sensing and computer modelling. Once again, it is best to use a secondary check to confirm your fruit maturity on the ground.

Key references

Australian mangoes crop forecast

Australian Tree Crop Map

Australian Tree Crop Map Dashboard- YouTube

Felix instruments: a quality meter for the mango supply chain

Felix instruments: brix as a metric of fruit maturity

Felix instruments: dry matter as a measure of maturity quality in mangoes

Fruitmaps.info heat units calculator for mango - YouTube

Mango forecasting with machine vision: how it works - YouTube

Mango ripening guide

Mango skin colour guide

Measuring dry matters - YouTube

Multi-scale monitoring tools for managing Australian tree crops – phase 2 project site

National tree crop mapping

Understanding heat sums - YouTube

Anderson, N.; Subedi, P. & Walsh, K. (2017). Manipulation of mango fruit dry matter content to improve eating quality. Scientia Horticulturae. **226**. 316-321.

Diczbalis, Y.; Wicks, C.; Landrigan, M. (1997) HRDC Heat sums to predict fruit maturity in mango (c.v. Kensington Pride) final report

Hosakote, Y.; Prabha, T. & Tharanathan, R. (2005). Mango ripening - Chemical and structural characterization of pectic and hemicellulosic polysaccharides. Carbohydrate research**. 340**. 1335-42.

Hossain, M. A.; Rana, M. M.; Kimura, Y., & Roslan, H. A. (2014). Changes in biochemical characteristics and activities of ripening associated enzymes in mango fruit during the storage at different temperatures. BioMed research international **2014**

Jha, S. N.; Jaiswal, P.; Narsaiah, K.; Kaur, P. P.; Singh, A. K., & Kumar, R. (2013). Textural properties of mango cultivars during ripening. Journal of food science and technology, **50(6).** 1047–1057.

Maldonado-Celis M.; Yahia Elhadi M.; Bedoya R.; Landázuri P.; Loango N.; Aguillón J.; Restrepo B.; Guerrero Ospina J. C. (2019) Chemical Composition of Mango (Mangifera indica L.) Fruit: Nutritional and Phytochemical Compounds Frontiers in Plant Science. **10.**

Moore, C.; Owens, G. & Connelly, M. (2010) HAL Developing a crop forecasting system for the Australian Mango Industry final report

Subedi, P.; Walsh, K. and Owens, G. (2007). Prediction of mango eating quality at harvest using short-wave near infrared spectroscopy. Journal of Postharvest Biology and Technology. **43.** 3

Subedi, P.; Walsh, K. & Purdy, P. (2013). Determination of optimum maturity stages of mangoes using fruit spectral signatures. Acta Horticulturae. **992**. 521-527.