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Australian Centre for International Agricultural Research

Final report

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Contents

Abbreviations

AUD	Australian dollars
CIRAD	French Agricultural Research Centre for International Development
DARD	Department of Agriculture and Research Development, Vietnam
EU	European Union
g	gram
GAP	good agriculture practices
GHG	greenhouse gas
HACCP	Hazards and Critical Control Points
HCMC	Ho Chi Minh City
HK	Hong Kong
HWT	hot water treatment
kg	kilogram
MARD	Ministry of Agriculture and Research Development, Vietnam
MRL	maximum residue levels
NMBP	National Mango Breeding Program
NPK	nitrogen, phosphorus and potassium
PBZ	paclobutrazol
ProCal	prohexadine chloride
SCAP	Southern Centre of Agriculture Rural Policy and Strategy
SIAEP	Sub-Institute of Agricultural Engineering & Postharvest Technology
SOFRI	Southern Horticultural Research Institute, Vietnam Academy of Sciences
UCZ	uniconazole-P
VND	Vietnam dollar

1 Acknowledgements

This technical report presents the findings of an ACIAR Project that involved an intensive collaborative research effort over four years between Griffith University (GU) and The University of Adelaide, in conjunction with three Vietnamese institutes: the Sub-Institute of Agricultural Engineering and Postharvest Technology (SIAEP), Southern Horticultural Research Institute (SOFRI), and Southern Centre of Agriculture Rural Policy and Strategy (SCAP).

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Project Reference Group

Vice Director, Department of Agriculture and Research Development (DARD), Dong Thap Province; Director, Centre of Extension and Agriculture Services, Tien Giang Province; Head of Agricultural Sciences, Can Tho University, Can Tho Province; Vice Director, Department of Science and Technology; Director, Long Uyen Company; Vice Director, Vina T&T; Director, Kim Nhung Packhouse, Dong Thap Province; Director, Ba Xoai Packhouse; General Secretary, Vietnam Fruit Association.

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The views expressed in this report are those of the research team and do not necessarily reflect the views of GU, The University of Adelaide, ACIAR or the governments of Australia or Vietnam.

2 Executive summary

Southern Vietnam's mango trade is a vibrant, multi-faceted business environment undergoing rapid development. The region produces 92% of the Vietnamese national mango output, mostly from small orchards less than 1.2 Ha on average. Planted areas, production and resulting trade have grown since 2005, and contribute significantly to the livelihoods of Vietnamese smallholder farming communities and the national economy.

The project aimed to improve the net income and livelihoods of smallholders in two provinces and contribute to the longer-term goal of developing a more sustainable and profitable mango industry. The project identified that in some instances income from mangoes represents 74.5% of total household income. Men remain the key decision makers in production and the main participants in cooperatives, with women playing a significant role in trading and marketing. Baseline consumer surveys identified 66% of consumers purchase mangoes once a week and 27% purchased mangoes more than twice a week. 30% of consumers purchase 2-3kg of mangoes per store visit, with most preferring a medium size fruit (300-500g).

This report examines opportunities and presents options to increase competitiveness in fresh and processed mango value chains, primarily from the perspective of smallholder mango production and domestic mango trade. Initial research activities looked at the diverse challenges facing mango value-chain stakeholders. Interviews and surveys were held to understand current practices, followed by interventions to provide evidence-based, proofs of concept designed to identify, test, and validate processes and models to improve trade. Activities were principally led by in-country researchers with strong connections to farmers, packhouse operators, cooperatives, and retailers.

The research identified a suite of common, critical supply chain barriers impeding trade. These pre- and post-harvest practices that impede trade were identified as applicable across all of Vietnam's mango-producing areas. The six areas validated as having the earliest ability to advance and improve mango production and supply. The project revealed:

1. Pre- and post-harvest diseases severity limits both domestic and export market potential. Simple effective treatments, such as mango bagging can successfully suppress pest and disease pressure and reduce chemical use, improve marketability, and increase farmer profitability.
2. Incorrect application of fertiliser is common, with overuse contributing to poor crop nutrition, impacting on fruit quality and disease susceptibility, and to environmental pollution.
3. Further work is needed to pursue the potential of off-season mango production.
4. A seasonal shortage of mangoes presents a future opportunity for trade with HK and the EU.
5. Benefits arise from sap treatment, HWT and boxing mangoes with consumers willing to pay almost double for high-quality, treated Cat Hoa Loc mangoes and up to 10 times the price of untreated varieties.
6. Improving consistency in supply, technology and infrastructure will support the growth of the processing mango sector.

Future impacts of the project will require practice change throughout the value chain, driven by market incentives. Specific attention to reducing excessive fertiliser application (which has negative greenhouse gas (GHG) emissions and impacts on ground and surface water), reliable supply of out-of-season fruit, development of fruit quality parameters related to consumer demand, progression of GAP-compliant mango production, and economic improvements through sap management and hot water treatment are key to value chain improvements.

The report recommends six opportunities for research investment to improve mango production and trade in southern Vietnam and other partner countries where mango farming is a priority for communities:

1. Develop a model mango disease-management system.
2. Develop and implement a mango orchard nutrition-research program.
3. Evaluate the commercial viability of hot water treatment for short, medium, and long-distance mango markets.
4. Strengthen public–private partnerships to improve the impact of research and innovation for trade.
5. Examine how trade partnerships in Hong Kong and/or the EU could advance exports for Vietnamese mangoes.
6. Initiate a policy dialogue to develop and advance the commercialisation of frozen processed mango and other tropical fruits in Vietnam.

3 Background

The project was commissioned to identify opportunities to improve mango production and trade from southern Vietnam and contribute to the longer-term goal of developing a more sustainable and profitable mango industry. Extensive consultations with stakeholders before the project began identified mangoes as a high priority for provincial and district governments in Vietnam. Mangoes were also endorsed as a priority fruit with a favourable market environment and the potential to benefit smallholder livelihoods.

The project included the southern Vietnam provinces of Dong Thap and Tien Giang, endorsed by the Vietnamese government as significant mango-producing regions with a high representation of smallholder farming communities. The activities focused on innovative, proof-of-concept research to improve mango supply competitiveness at on-farm, postharvest and retail points along the chain.

The key drivers of the project were:

- the significance of mango trade from southern Vietnam
- partner country and Australian research issues and priorities related to export development
- opportunities for research and development to advance mango exports.

The significance of mango trade from southern Vietnam

The production, processing and consumption of mango in southern Vietnam is a dynamic and multifaceted trading environment undergoing rapid development. Mango production, planted area and trade has increased since 2005, and contributes significantly to the livelihoods of Vietnamese smallholder farming communities and the national economy (Figure 3.1). Almost half of Vietnam's mangoes are produced in the Mekong Delta region. This important economic centre supports over 15 million people and contributes around 27% of Vietnam's gross domestic product.

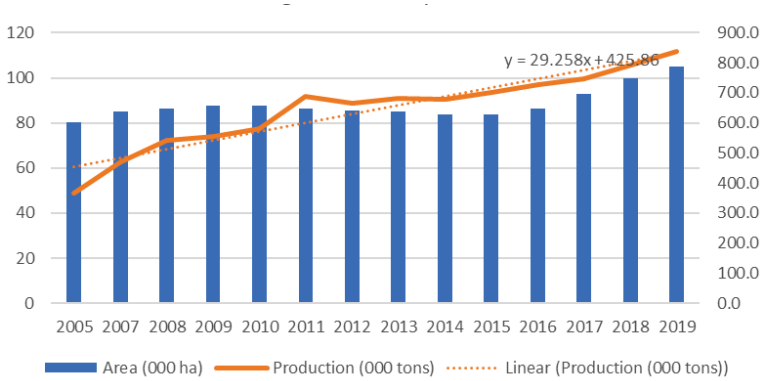

Figure 3.1 Rise in mango planted area and production, Vietnam, 2005–2019

Source: Activity analysis

As mentioned, the selection of mango as the priority fruit results from the favourable market environment and the significant potential benefits to smallholder livelihoods and communities in southern Vietnam. Contributing indicators include the:

- robust domestic and export market demand
- high government priority for development
- extensive smallholder production base
- potential to adopt a wide range of improvements in production and trade
- private sector's willingness to participate in research for development
- alignment with Australian expertise in mango research.

Partner country and Australian research issues and priorities

The project and provincial focus were conceptualised using the priorities laid out by the Vietnamese government for the sector. Decrees issued include planning of major fruit regions, intensive cultivations and flowering orientation (Decree No. 1648/QBNNTT), policy support to reduce losses in agriculture (Decree No. 6820013/QDTTG), and policies that encourage enterprises to invest in mango farming in rural regions (Decree No. 2102013/NDCP). In addition, the project aligns with four areas identified in the 2014/25–2018/19 Australian Mango Industry Strategic Investment Plan – market attractiveness, protocol improvement, market development and product improvement opportunities.

Opportunities for research and development to advance the mango trade

In Vietnam, most past research has focused on the technical aspects of agronomy and tree management, and to a lesser extent on postharvest quality and processing technologies. There has been limited focus on refining and extending pre- and post-harvest treatment techniques to maximise fruit quality and shelf life. Knowledge of post-harvest losses, trader and processor practices, market preferences and value addition potential did not exist. This project sought to address research-for-development gaps in a structured framework, using proof-of-concept interventions that could improve mango exports and contribute to smallholder farmers' livelihoods and other actors in the fresh and processed mango chains in southern Vietnam.

Our initial studies identified and supported relevant research areas and the focus of subsequent intervention activities. These included:

- understanding effective off-season cultivation (flower manipulation techniques)
- improving postharvest handling and chain management with retailers
- identifying prospects for farmers to supply excess fruit to processors for freezing to provide alternative income.

Off-season cultivation and flower manipulation

Thiourea is the one of the main chemicals used to manipulate flowering in Southeast Asia. While thiourea is not residual in the fruit, it is highly carcinogenic for mango farmers. Past ACIAR research in Cambodia and Australia evaluated the efficacy of alternative products and flowering management practices. This project expanded on these techniques to widen the harvest window in smallholder farms and communes, which would spread out supply and improve farmer margins. We sought to understand, develop and refine off-season flowering techniques to benefit Vietnamese and Australian mango industries.

Managing excess fruit supply and reducing losses

To extract the most value from all grades of mango, close cooperation with private-sector fruit processors is essential. Frozen whole cheeks command the highest price. However, blemished and sub-optimal fruit can be processed into products such as jam, juice, puree and pulp, which are not dependent on texture or appearance. The processing sector could extract more value by freezing and using mangoes that are currently wasted. This would provide viable pathways to link smallholder-produced fruit to processors.

Fresh, high-quality mangoes are clearly optimal for modern retail trading. But the proportion of such fruit in the harvest is limited by sub-optimal postharvest handling, poor infrastructure, delays, long distribution chains, and poor storage at retail and processing centres. This project sought to engage in research activities with retailers and processors to investigate upstream and downstream supply chains to address losses, improve agricultural practices and understand market demand.

4 Objectives

The overall aim of the project was to improve the net income and livelihoods of smallholders by increasing the competitiveness of selected mango value chains in two provinces in southern Vietnam: Dong Thap and Tien Giang. Three research areas are linked to the three project objectives, as described below.

Research area 1 – Identify and prioritise supply chain and market development opportunities.

- What on-farm, postharvest, marketing and processing innovations are likely to generate the most significant impacts to reduce losses, increase productivity and quality outputs that will improve returns directly related to smallholder incomes?
- Which innovations are likely to modify labour intensity in a gender-balanced way?
- What improved good agricultural practice (GAP), plant nutrition, disease and pest management models have the greatest potential to reduce the negative effects of agrochemical use on farmers, the environment and the end consumer while being able to produce affordable, quality fruit?
- Is selling processing-grade mangoes a viable proposition for smallholder farmers, and if so, how can they improve their competitiveness to access the processing segment of the market profitably?
- Is the export market to Hong Kong attractive and feasible for mango export from southern Vietnam and Australia?

Research area 2 – Test and evaluate innovative supply chain interventions.

- What interventions have the most cost-effective and positive impacts on productivity, losses, quality and harvest timing, leading to improved price and farmer incomes?
- What is the potential to increase farmer incomes from further developing access to processed fruit chains in the domestic market?
- What opportunities exist to empower women in existing mango value chains, and what targeting strategies could broaden livelihood and improve development outcomes for women?
- What processes will strengthen market linkages and agribusiness partnerships (public and private sector) and increase innovation adoption along the value chain?

Research area 3 – Develop critical capacities, tools and services for mainstreaming chain innovations.

- What tools will support sharing of innovations with wider mango farming communities?
- How can these tools be developed and delivered in the realistic context of the infrastructure in the two provinces?
- What role can new media play in increasing return for effort across the life of the project?
- What are the roles and responsibilities of the key local partners to ensure the innovations are taken up by the communities in southern Vietnam?

Objective 1 – Identify and prioritise supply chain and market development opportunities.

1.1 Identify and confirm smallholder collaborators in Dong Thap and Tien Giang based on agreed selection criteria and stakeholder consultation.

1.2 Complete a stratified, baseline, socio-economic research study of men and women in mango farming households in the targeted districts.

1.3 Understand current seasonal flowering practices and on-farm production issues.

1.4 Understand the mango market situation and segments in HCMC and Hanoi.

1.5 Understand current value chains for fresh and processed mango from Dong Thap and Tien Giang to HCMC and Hanoi.

1.6 Evaluate factors affecting fruit quality benchmarks.

1.7 Conduct an export market case study in Hong Kong for Australian and Vietnam mangoes.

1.8 Undertake domestic wholesale market price monitoring in HCMC and Hanoi during seasonal supply periods for mango.

1.9 Undertake participatory appraisal and selection of key issues and intervention options in stakeholder workshops.

Objective 2 – Evaluate options to overcome selected barriers to competitiveness in fresh and processed mango value chains.

2.1 Design, develop and implement participatory research interventions to improve fruit productivity and quality at the farm level.

2.2 Design, implement and evaluate improvements in expanding seasonal flowering practices.

2.3 Identify and demonstrate opportunities for improving productivity and quality in fresh mango supply chains.

2.4 Establish a partial PROCESSING trial as a methodology for mango season extension and productivity improvement.

2.5 Undertake financial, economic, and business feasibility analysis and validation on selected interventions in activities A2.1 to A2.4.

Objective 3 – Improve capacity, industry stakeholder linkages and knowledge sharing.

3.1 Identify and establish a multi-stakeholder mango reference group and organise regular meetings to provide ideas and engagement into the project.

3.2 Conduct annual stakeholder workshops with a wider stakeholder group to strengthen linkages and share project progress and experiences.

3.3 Undertake chain linkage-building activities with key stakeholders for adoption of targeted interventions.

3.4 Design and develop training guides and supporting information for distribution to wider industry participants (farmers, traders, retailers).

3.5 Deliver train-the-trainer designed workshops for mainstreaming project innovations with key industry champions and leaders including extension officers.

3.6 Review and evaluate project outputs (interventions, training and communication strategies). Identify three priority capacity development areas for next project phase.

5 Methodology

5.1 Research approach and timing

This project used a mixed methods design to capture research information from September 2018 to June 2022.

5.1.1 Study impacts and interruptions

The first wave of COVID-19 in Vietnam presented in late January 2020. Research activities were ceased from February 2020. By May 2020, movement restrictions and delays due to increased family duties severely limited the available time for research activities. Vietnam suffered a further three waves from the pandemic between July 2020 and December 2021.

From 1 July 2020 to 30 June 2022, the project partners agreed with ACIAR to formally vary the project (non-financially) by extending activities for an additional year. This reduced all research contributions by 50% over the two years. Research activities were considerably scaled back, and some activities could not be completed due to impacts from pandemic restrictions.

5.1.2 Research design – approach

The project involved setting up proof-of-concept activities, also known as interventions, to improve mango quality (production, processing, trade) across the mango value chain. This was achieved by engaging stakeholders (smallholder farmers, collectors, packhouse operators, cooperatives, wholesalers, and retailers) and linking them with researchers. Provincial officials, known as extension officers, were engaged to educate the farmers about the interventions. Involving extension officers allows information to be disseminated more widely and can increase the uptake of interventions.

As indicated in Section 3, the working hypothesis was to test evidence-based interventions to increase competitiveness and business sustainability through improving practices in the mango supply chain. This required a multiple case-study approach. The first step was to understand mango supply in southern Vietnam, while the second was to identify areas for improvement, test relevant interventions and validate the effectiveness of the changes.

The first activity confirmed the key stakeholders within the identified provinces: Dong Thap and Tien Giang. The most recent available data (from 2017) was used for decision-making purposes at the start of the project.

Dong Thap and Tien Giang are both located in the Mekong River Delta, the key region for tropical fruit production in Vietnam. In 2017, it was the largest mango production region in the country, with 45,100 hectares, or 45.2% of the national total. Dong Thap and Tien Giang accounted for around 32% of the total production area in the Mekong River Delta, and almost 50% of total mango output (Table 5.1). The main varieties grown in this area are Cat Hoa Loc and Cat Chu mangoes.

Table 5.1. Area of mangoes planted, Mekong River Delta, Vietnam, 2005–2017

Region	Hectares per year					
	2005	**2009**	**2010**	**2015**	**2016**	**2017**
Country – Total	80,100	87,600	87,500	83,700	86,700	92,700
Mekong River Delta – Total	38,200	43,500	43,190	39,000	41,900	42,725
Dong Thap	**6,143**	**8,892**	**9,300**	**8,656**	**8,768**	**9,128**
Tien Giang	**6,072**	**6,612**	**6,657**	**4,574**	**4,693**	**4,710**
Remaining Mekong River Delta Provinces (11)	25,985	27,996	27,233	25,770	28,439	28,887

Source: GSO, 2018

The project focused on the government-nominated provinces of Cao Lanh City and Cao Lanh District in Dong Thap, and Cai Bei in Tien Giang, to study fresh and processed mango production and trade (Figure 5.1).

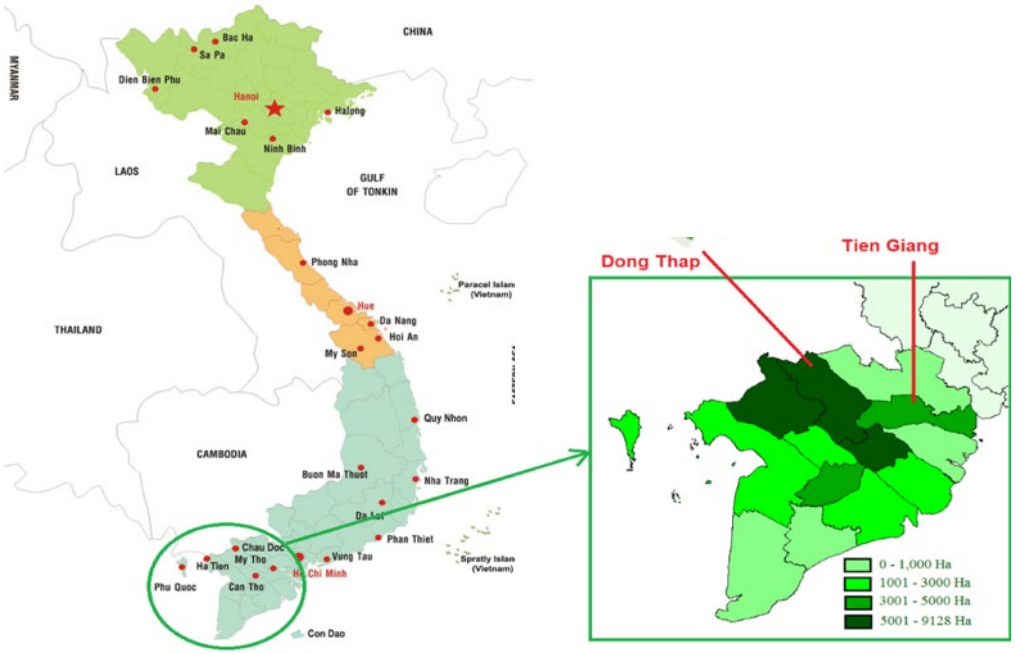

Figure 5.1. Distribution of mango production area in the Mekong River Delta region, 2017

Source: Activity analysis

The project was launched in September 2018 in Dong Thap. A significant number of stakeholders from government and private-sector organisations attended. Foundation research, consisting of semi-structured interviews and focus group activities, was carried out in Dong Thap, Tien Giang and HCMC between October 2018 and December 2019. Primary research studies (interventions) were undertaken between July 2021 and June 2022.

The project was extended until 30 September 2022 to complete the final intervention activities – Demonstration Chain, Walking the Chain (farmer field activity), and the intervention analysis and validation, concluding with a final project review workshop in September 2022 in HCMC.

5.2 Research methods

The project partnerships (in-country) were led by three Vietnamese institutes: SIAEP, SOFRI and SCAP. Each institute was strategically chosen as a collaborator, with the view to build researcher skills and knowledge in mango (on-farm, postharvest and trade marketing).

As mentioned, the COVID-19 pandemic severely impacted the project's activities. However, the re-engineering required to continue the project improved the planning and delivery of the activities and augmented the development of individual researchers through training and focusing on specific points in the supply chain.

Objective 1 – Identifying opportunities to increase competitiveness

In the first year of the project, we determined a household socio-economic baseline by interviewing householders in the regions of interest. The surveys aimed to understand socio-economic and demographic characteristics related to mango farming and market practices, resource endowments (land and productive resource access, income sources, and labour allocation), gender roles and orchard management systems. This involved:

- enumerator training, survey development and survey pre-testing (20 farmers)
- training in software and tablet use for in-field surveys of farmers
- training all researchers to ensure understanding related to applying a gender lens across the activities
- holding survey interviews (227 households) in three districts – Cao Lanh City (81) and Cao Lanh District (75) in Dong Thap, and Cai Be District (71) in Tien Giang.

Research to understand current practices and on-farm issues in mango cultivation (production and flowering) was completed in the first 18 months of the project. This work encompassed:

- reviewing published studies
- developing training and interview checklists for field research in HCMC and provinces
- holding 40 semi-structured interviews in Dong Thap and Tien Giang.

Market evaluation to examine the mango trade in HCMC and Hanoi, including segments, channels and consumer usage and attitudes, was also completed in the first 18 months of the project. This involved:

- reviewing published studies
- identifying stakeholders – collectors (who transfer mangoes for the farmer to a trader or packhouse operator), traders, wholesalers, retailers and food service
- developing training, checklists and observation recording sheets, gaining ethical approval, practising interview techniques
- completing 26 trader interviews and direct observation studies, analysing interview transcripts and reporting
- analysing 1105 online consumer surveys to study preference, attitudes and willingness to pay for mangoes, followed by descriptive and regression analysis for reporting.

The first year of the project also saw studies of fresh and processed mango supply completed, to examine the current value chains from Dong Thap and Tien Giang to HCMC. This work involved:

- reviewing published studies
- semi-structured interview training, checklist development and pre-testing of the survey completed

- engaging with farmers, collectors, wholesalers, and retailers who engaged with three nominated packhouses
- performing value-chain assessments in two provinces, which included the interconnected primary and supporting stakeholders and local extension officers
- chain mapping, analysis and reporting.

Objective 2 – 'Proof-of-concept' intervention trials

A selection of value-chain stakeholders (and reference group members) was invited to participate in the intervention selection, and preparation and planning of trials. Group workshops were held relating to on-farm and postharvest activities, which included discipline-specific researchers from the in-country institutes.

The intervention trials selected included:

- best-practice disease and pest management (on-farm)
- fertiliser management – Cat Chu and Cat Hoa Loc mango varieties (on-farm)
- HWT – southern Vietnam trial (on-farm and institute)
- expanding seasonal flowering (on-farm)
- improving mango productivity and quality in fresh supply chains (packhouse and retailer)
- processed mango freezing (processor and institute).

Due to travel restrictions, bespoke online training and development workshops were run for in-country researchers. For example, online training was conducted for Nutrition Management and Impact Assessment. This educated researchers on why a systematic approach is used for study design, data collection and outputs. The researchers gained a certified micro-credential certificate (Figure 5.2).

Figure 5.2. Examples of micro-credential certificates for Impact Assessment and Nutrition Management training

Source: Activity image

Together with chain stakeholders, the following intervention activities were evaluated within the demonstration chain – sap burn, HWT, packaging and retailing – with a focus on the stakeholders' capability to adopt the changes into industry practice to advance the mango trade.

Objective 3 – Building connectivity and capacity

The third objective encompassed the project's connectivity. This included:

- engaging with stakeholders (e.g. reference group meetings)
- disseminating and communicating the outputs (e.g. project website)
- delivering linkage activities, such as 'Walking the Chain'
- developing training and education resources, and delivering train-the-trainer workshops
- consolidating the project's outputs for mainstreaming.

6 Achievements against activities and outputs/milestones

Objective 1: Identify opportunities to increase competitiveness and empower women in fresh and processed mango value chains.

No.	Activity	Outputs	Completion	Comments/ Evidence source
1.1	Identify & confirm smallholder collaborators in Dong Thap & Tien Giang based on agreed selection criteria & stakeholder consultation.	Scoping studies reviewed; 270 smallholder collaborators identified & confirmed to participate in project Lead: SIAEP/GU	September 2019	Inception meeting with partners & collaborators to formalise participation completed. A briefing document (Terms of Reference) for selection of appropriate collaborators (farmers, local/district traders) & agreed selection criteria (e.g. farm size, number of trees, production experience/skills, market linkages) – shared & discussed with DARD & Provincial People's Committees. https://apmangonet.org/wp-content/uploads/2020/01/VN-2019-Act1.1_Proj-collaborators.pdf
1.2	Complete a stratified baseline socio-economic research study of men & women in mango farming households in the targeted districts.	A detailed report presenting financial & socio-economic situation analysis of targeted households, and including gender roles, issues & opportunities for empowering women Lead: CIRAD/SCAP	April 2020	Training to support planning & implementation of the baseline study undertaken. 227 surveys captured in Dong Thap (Cao Lanh District, Cao Lanh City) & Tieng Giang (Cai Bei) provinces. Study results delayed to the pandemic & the departure of the lead researcher. https://apmangonet.org/wp-content/uploads/2020/05/AGB2012061-A1.2-HH-Baseline-study.pdf
1.3	Understand current seasonal flowering practices & on-farm production issues.	A detailed report outlining current farming practices including GAP, an assessment of existing skill levels & identification of key opportunities regarding flower manipulation practices and increasing mango productivity and quality Lead: NTDPI/SOFRI	April 2020	Review of published studies relating to production & flowering practices completed. Semi-structured interviews to understand current on-farm production practices with 20 farmers in Dong Thap & Tien Giang completed. Opportunities to implement practice change via 'proof-of-concept' interventions were identified. https://apmangonet.org/wp-content/uploads/2020/05/AGB2012061-A1.3-Production-Flowering-study.pdf

No.	Activity	Outputs	Completion	Comments/ Evidence source
1.4	Understand the mango market situation & segments in HCMC & Hanoi.	*Key milestones:* - Research instruments designed & tested - Team training completed - Market data collected & analysed Completed market situation & segmentation study, preliminary usage & attitude consumer report identifying demand driver & quality perceptions to provide baseline information for on-farm & chain innovations Lead: UoA/SCAP	Years 1 & 2	Practical training, design & testing of research instruments, data analysis & reporting completed. Reports prepared included: • Desktop review of markets & consumption • Market assessment with operators in various market segments • Online consumer study https://apmangonet.org/wp-content/uploads/2020/05/AGB2012061-A1.4-Market-Review.pdf https://apmangonet.org/wp-content/uploads/2020/05/AGB2012061-A1.4-Market-Assessment-1.pdf https://apmangonet.org/wp-content/uploads/2021/02/AGB2012061-A1.4-Consumer-study.pdf
1.5	Understand current value chains for fresh & processed mango from Dong Thap & Tien Giang to HCMC & Hanoi.	Completion of value-chain reports including opportunities for chain innovations & potential impacts Lead: Peter Johnson/Richard Beyer/SIAEP	Years 1 & 2	These two studies were completed in the first part of the project. Workshop training, covering checklist development, interviewing, & writing up research was undertaken. Interviews were conducted in Dong Thap, Tien Giang provinces & in HCMC. Team members were new to this type of activity & as such the level of details was constrained. The significant findings were summarised & reported, & key interventions were identified. https://apmangonet.org/wp-content/uploads/2020/05/AGB2012061-A1.5-VC-Fresh.pdf https://apmangonet.org/wp-content/uploads/2020/05/AGB2012061-A1.5-VC-Processed.pdf
1.6	Evaluate factors affecting fruit quality benchmarks.	Data generated identifying critical quality control points Report presenting current quality management practices in short & long-distance chains including quantifying, postharvest & physical losses Lead: SOFRI/GU	Years 1 & 2 Focus continued throughout the project.	A review of published studies, observational & interview field research conducted. Key areas for the potential to enact change & improve mango quality across the value chain was identified. https://apmangonet.org/wp-content/uploads/2020/05/AGB2016021-A1.6-Quality-study.pdf

No.	Activity	Outputs	Completion	Comments/ Evidence source
1.7	Conduct an export market case study in Hong Kong for Australian & Vietnam mangoes.	A report documenting importers, processors, customer preferences & chain implications Lead: UoA/GU/SCAP	June 2022	A review of literature on HK mango trade was completed, along with an initial in-market study (observational & interviews) undertaken by a HK researcher (resident in country). Due to the pandemic this study was not possible to complete. The research team in conjunction with the interests of the Australian mango industry chose to study the export opportunity for mangoes in United Kingdom, France & Germany. http://vietnammangonet.org/wp-content/uploads/2021/07/A1.7-Hong-Kong-Study_-Stage-1.pdf http://vietnammangonet.org/wp-content/uploads/2022/05/A1.7_Hong_Kong_Review_of_Published_Studies.pdf http://vietnammangonet.org/wp-content/uploads/2022/08/Export-Markets-ENG.pdf
1.8	Undertake key domestic wholesale market price monitoring in HCMC & Hanoi during the seasonal supply periods for mango.	A series of reports that capture seasonal mango market pricing over a three-year period from three of the largest wholesale markets in Vietnam Lead: UoA/SCAP (Previously CIRAD)	2021 & 2022 seasons	Practical training & preparation was conducted with researchers capturing the information in the three markets. Survey data was captured, analysed & shared by the SCAP & UoA teams with the wider project group. http://vietnammangonet.org/wp-content/uploads/2021/06/A1.8_Market-monitoring-study-WPJune2021.pdf http://vietnammangonet.org/wp-content/uploads/2022/05/A1.8_Market_Monitoring_Final.pdf http://vietnammangonet.org/wp-content/uploads/2022/05/A1.8_Market_Monitoring_Final_Appendix.pdf

No.	Activity	Outputs	Completion	Comments/ Evidence source
1.9	Participatory appraisal & selection of key issues and intervention options in stakeholder workshops.	Key milestones: - Research interventions, analysed, reviewed & ranked by impact potential - Selection of proposed intervention activities - Intervention activities, costs & timelines documented & agreed to by research team Lead: GU/SCAP	October 2019	Proposed interventions were ranked, assessed & agreed to by project stakeholders at the annual workshop 'Oct '19. Note: Foundation knowledge was presented & disseminated for discussion at the end of Year 1 workshop in October 2019. Interventions with the potential to deliver chain improvements were identified, & the research design & methodology to evaluate the activities was planned. Due to the COVID-19 pandemic, the Year 2 activities were reviewed in February 2020, & again in May 2020.The project has revised activities to be delivered through online-based training & team communications which has allowed the project to continue (with modified time & resources).

Objective 2: Evaluate options to overcome selected barriers to competitiveness in fresh and processed mango value chains.

No.	Activity	Outputs	Completion	Comments / Evidence source
2.1	Design, develop & implement participatory research interventions to improve fruit productivity and quality at the farm level.	Trial interventions designed Complete trial team training workshops Select and confirm trial sites Undertake interventions Progress report Review & refine for next season – output as preliminary report Final reporting and production of best-practice material Lead: GU/SOFRI	June 2022	Six studies were undertaken to test interventions in this activity & reported in the next section. Full reports can be viewed at: - Diseases of mango – management of anthracnose and black spot - Best practice disease and pest management - Effect of NPK dosage application on Cat Hoa Loc mangoes - Effect of NPK dosage application on Cat Chu mango - HWT – to study the control of mango postharvest disease for longer distance supply chains in Vietnam (scientific paper in progress) - HWT – impact on new Australian mango varieties (scientific paper in progress) Resource material: Video Presentations for demonstration training

No.	Activity	Outputs	Completion	Comments / Evidence source
2.2	Design, implement & evaluate improvements in expanding seasonal flowering practices.	Identify flowering interventions Complete team training workshops Confirm trial sites Undertake trials Progress report Review & refine for next season – output as preliminary report Final reporting including production of field guide Lead: GU/SOFRI	June 2022	Two studies were undertaken to identify feasibility to expand seasonal flowering practices. One full report can be viewed at: PBZ alternative and impact study – Interim 2021 PBZ alternative & impact study – Final 2022 (scientific paper in progress) Resource material: Video Presentations for demonstration training
2.3	Identify & demonstrate opportunities for improving productivity and quality in FRESH mango supply chains.	Workshop completed to design & implement quality improvements in fresh chains including evaluation criteria Monitoring of planned interventions Results analysed Review & refine for next season – output as progress report Final reporting, production of best-practice material Lead: GU/SIAEP	June 2022	Four studies were undertaken that identified four key areas for scaling out & scaling up in future development work for the mango industry in southern Vietnam. The Demonstration Chain study confirmed the benefits of: -improved sap management - the role of HWT in improving mango quality -benefits to change practice at farm/packhouse levels to deliver mangoes in acceptable retail formats - Management of sap burn and trolley study interim 2021 - Sap management study final 2022 - Trolley Study - Demonstration Chain Study - Demonstration Chain Study Appendices Resource material: Video Presentations for demonstration training
2.4	Establish a partial PROCESSING trial as a methodology for mango season extension and productivity improvement.	Key milestones: - Workshop completed to plan a chilling & freezing trial - Undertake & monitor trial - Progress report - Results analysed, cost benefit analysis completed & results shared in a forum - Final reporting Lead: GU/SIAEP	June 2022	This activity completed the partial trial for mango freezing & produced 2 Guides – A Procedural Guide and a Code of Practice. - Processed Mango Code of Practice - Processed Mango Recommended Procedure Guide - Processed Mango – Freezing trial study - Processed Mango Freezing trial interim report

No.	Activity	Outputs	Completion	Comments / Evidence source
2.5	Undertake financial, economic & business feasibility analysis and validation on selected interventions in A2.1 to A2.4.	A summary report of the outputs from interventions & present recommendations to achieve broader market development including financial benefits that might be allocated more fairly through the supply chain Lead: UoA/SCAP (prev. CIRAD)	June 2022	Analysis & validation was undertaken with evidence provided by three documents: - Analysis & validation Interim report - Analysis & validation final report - Analysis & validation – supporting Appendices See Mid Review presentations

Objective 3: Improve capacity, industry stakeholder linkages and knowledge sharing.

No.	Activity	Outputs	Completion	Comments/ Evidence source
3.1	Identify & establish a multi-stakeholder mango reference group & organise regular meetings to provide ideas & engagement into the project.	Formation of Reference Group Confirmation of group meeting schedule Input from group into trials & adoption strategies Lead: GU/SIAEP	Aug 2019	Years 1 & 2 the project held two multi-stakeholder mango reference group meetings. When the pandemic hit Vietnam, the ability to organise a meeting was challenging. The health & environmental challenges posed by the pandemic meant stakeholders were focused on their families & own working environments. Further, they had limited access to the appropriate technology to participate in online meetings. From Year 4, meetings were held with a range of stakeholders to form the Demonstration Chain working group to implement the interventions & engage with provincial stakeholders (farms, collectors, packhouse operators & retailers).
3.2	Conduct annual stakeholder workshops with a wider stakeholder group (50 to 60 participants) for strengthening linkages & sharing project progress & experiences.	Publish workshop dates Workshops conducted Develop annual work plans Lead: GU/SIAEP	Completed	Annual ACIAR reporting was completed – 2019, 2020, 2021 & along with annual project workshops (planned with agendas & timetables) placed on project website. To assist with whole-of-team communications & resource dissemination an open-access website was implemented – www.vietnammangonet.org

No.	Activity	Outputs	Completion	Comments/ Evidence source
3.3	Undertake chain linkage-building activities with key stakeholders for adoption of targeted interventions.	Successful communication & engagement strategy for the adoption of agribusiness improvements in mango production and supply chains Lead: GU/SIAEP/SOFRI/SCAP	June 2022	During the first 16 months the project team engaged in 21+ workshops & meetings. In the post-pandemic period Jul 2019 to Jun 2022, the team had 50+ workshops, meetings & virtual training sessions. The team continued to find innovative ways to communicate, engage & seek solutions to the undertaking & adoption of practice change that emerged from the project activities.
3.4	Design & develop training guides & supporting information for distribution to wider industry participants (farmers, traders, retailers).	Training packages developed Series of guides developed Lead: GU/UoA/SOFRI/SCAP	June 2022	A range of training resources were developed by the project. Traditional & digital formats in English & Vietnamese were prepared & delivered by the in-country partners (see Section 8 for examples).
3.5	Deliver train-the-trainer designed workshops for mainstreaming project innovations with key industry 'champions' & leaders including extension officers.	Key milestones: - Workshop specific content planned - Selection of proposed activities agreed with key research contributors - Workshop activities, costs & timelines planned - Completion of 12 train-the-trainer workshops per season for on-farm, value chains, processed & extended flowering - Training effectiveness evaluated & further training needs identified Lead: GU, UoA SIAEP, SOFRI, SCAP (prev. CIRAD & NTDPI)	June 2022	Training aligned to support each intervention activity was undertaken (either online or in-person). The training for all activities, at times was somewhat restricted due to travel restrictions, and the viability of online versus in-person training.

No.	Activity	Outputs	Completion	Comments/ Evidence source
3.6	Review & evaluation of project ouputs (interventions, training and communication strategies) Identify three priority capacity development areas for next project phase.	Key milestones: - Preparation of evaluation tools for each activity within the project to measure, monitor and outputs - ~~Completion of evaluation reports for each training, intervention & communication activity throughout the project~~ ~~- Identification of priority capacity development for R&D activities in next stage (Phase 2)~~ ~~- Feedback received on draft report~~ ~~- Preparation of initial Phase 2 proposal from IHR~~ ~~- Feedback received & revisions completed~~ ~~- Completion of Phase 2 proposal~~	June 2022	Years 1 to 4 annual reports were completed. The Project received a formal (no cost) variation by 12 months to June 2022. Variation meant that project personnel funding, resources & dedicated time for the final two years was effectively halved from July 2020 to June 2022 compared with the original proposal. The Phase 2 proposal & planning has been removed from the activity list post feedback from Program Manager & mid-term review. Activity plans were developed each year & are accessible on the project website: www.vietnammangonet.org

7 Key results and discussion

The production and trade of mangoes from southern Vietnam is changing, with trade and consumption predominantly contained within the country. Hence, this project focused primarily on the Vietnamese domestic market. The project activities were undertaken over two periods.

In the first period of the project (September 2018 – January 2020), key points in southern Vietnam's mango supply chains were identified with a view to improving productivity and competitiveness in the domestic trading environment. The research results for Objective 1, set out in Section 7.1, are the largest component of this report, and provide the foundation knowledge to inform the activities undertaken in Objective 2.

In the second period of the project (March 2021 – June 2022) areas of potential change to the mango production and trade were identified and studied via proof-of-concept interventions. This section presents the knowledge and evidence gained from the project, which indicates the effectiveness of the tested interventions and the likelihood of generating practice change in mango production and trade. The results are explained in detail in Section 7.2.

Section 7.3 presents the project's stakeholder engagement, linkage and capacity-building activities. Partnerships between public and private stakeholders are emerging in southern Vietnam as the industry is developing on-farm, post-harvest and in trade.

Section Summary

- A survey of 227 households identified that income from mangoes represents 74.5% of total household income, with re-investment into improving mango production.
- Farmer cooperatives are diverse and dynamics with growing membership with both traders and consumers approaching cooperatives to access fruit supply.
- Men remain the key decision makers in production and the main participants in cooperatives, with women playing a significant role in trading and marketing.
- Significant opportunity exists to improve farmer capacity throughout the chain, from managing inputs and production, through to postharvest management and marketing.
- Chemical use is high, with some growers reporting 12-13 sprays per season, which are often applied in a 60–80-day period.
- Trials found that nitrogen fertilisers were both overused (up to 10 times more than recommended) and underused, indicating improved management knowledge is required.
- Fertiliser application can be lowered without negatively effecting fruit quality.
- Fruit bagging, in conjunction with chemical control strategies reduces disease incidence and severity
- HWT can reduce postharvest disease and improve shelf-life for short and medium-distanced markets.
- Although results were variable, de-sapping treatment lowered sap-burn significantly.
- Up to 30% of mangoes grown could end up being processed, which are mainly exported with waste management a significant issue for processors.
- Using best practice significantly reduces production costs and improves farm profitability.
- Government policy emphasis organic processes, managing soil health and nutrition, and limiting the impact of climate change.
- Farm profitability is influenced by farm size, mango variety grown and seasonal supply window.

- Retail sales are affected by appearance, quality, readiness to eat and certification, with pricing influenced by season, quantity and quality.
- Surveys indicate 66% of consumers purchase mangoes once a week and 27% purchased mangoes more than twice a week. 30% of consumers purchase 2-3kg of mangoes per store visit, with most preferring a medium size fruit (300-500g).

7.1 Objective 1

This objective aimed to gain a foundational understanding of the trading environment for fresh and processed mango from southern Vietnam in the first 12–18 months of the project. It highlights the opportunities for and challenges in growing the Vietnamese mango trade, particularly for smallholder producers.

Activity reports presenting the full studies are available on the project weblink.

7.1.1 Stratified socio-economic study of mango farming households

Results – Household survey

Demographic summary: 227 household surveys were completed. All households were from the Kinh ethnic group. The average household size was four occupants, with the majority of farmers (96%) being married. The level of education was generally low, with only one-third of the farmer-led households completing high school or university.

The main insights from the surveys are summarised below.

Household socioeconomics

- Mango income represents on average 74.5% of total household income. This confirmed that households rely on mango production, and successful project interventions could significantly improve smallholder livelihoods.
- Most farmers appeared well-endowed in terms of equipment and social capital. However, one limitation of this study is that the cohort of participants organised and surveyed at local level did not necessarily reflect the characteristics of farmers that took part in later research activities. In future projects it will be important to spend more time planning survey activities, as well as ensuring prior stakeholder engagement to ensure that the process is clear and transparent.
- Most farmers had savings and dedicated a higher share of total income to re-invest back into mango production, followed by daily expenses and then household savings.
- Most farmers were highly specialised mango producers during the main and off-seasons. A small number of members worked as civil servants in the off season.
- Spouses also participated in agricultural work, with most farming their own crop during the main mango season. Many remaining spouses indicated housework as their main activity, with the remainder being engaged as civil servants, retired, or as shopkeeper/collectors.
- A high proportion of the farmers had collective responsibility within cooperative organisations. Networking and information access is vital for these groups.
- Gender imbalance at household level was noted in production activities and decision-making, which were skewed towards men. At a trade/marketing level, women buyers were common.
- Men dominated participation in cooperatives. We noted this to ensure that later intervention activities included women.

Farming practices

- Cat Chu and Cat Hoa Loc mango varieties were the focus of the sampled farms. A noteworthy proportion also cultivated the Taiwanese mango variety – especially in Cao Lanh City district in Dong Thap.
- Price patterns for Cat Hoa Loc differed from Cat Chu and Taiwanese mango varieties (see further consideration in Section 7.1.2).
- Village collectors-controlled quality based on criteria that are easily assessed – size and colour of fruit, and absence of defects at time of sale.
- Certified standards are not common practice, with cost for certification incurred by local authorities (the local standard being VietGap). Only farms with certification (VietGap or GlobalGap) were able to earn price premiums.

7.1.2 Seasonal flowering and on-farm practices and issues

This activity was designed to provide an understanding of current flowering and on-farm production practices, to identify innovations that will improve mango production and trade.

Results – Review of studies and farmer interviews

- Mango production in southern Vietnam has increased since 2010.
- Southern Vietnam is a key mango growing area, representing 92% of the national output. The provinces with the largest mango plantings are Dong Hai (~12,000 ha), An Giang and Dong Thap (both ~10,000 ha).
- The current management system for increased yields uses high levels of chemicals, water, fertilisers, and sprays, which raises input costs for farmers.

General management of flowering and cropping

- Mango flowering and cropping is carried out over a 12-month cycle. Management starts with pruning and fertilising after harvest to stimulate new growth.
- Subsequent growth is monitored to target specific growth stages and cropping dates to apply paclobutrazol (PBZ) to the soil, which reduces tree vigour and builds reserves to support fruit growth. The trees' responsiveness to chemical treatments is increased by foliar nutrient treatment.
- Chemicals are applied to simulate the effects of cold temperatures and bud growth to cause flower induction. A signal generated by the leaves is transported to the growing terminal and results in flower initiation.
- During flower development through to early fruit development, nutrients and growth regulators are applied to increase fruit set and retention (see Figure 7.1).

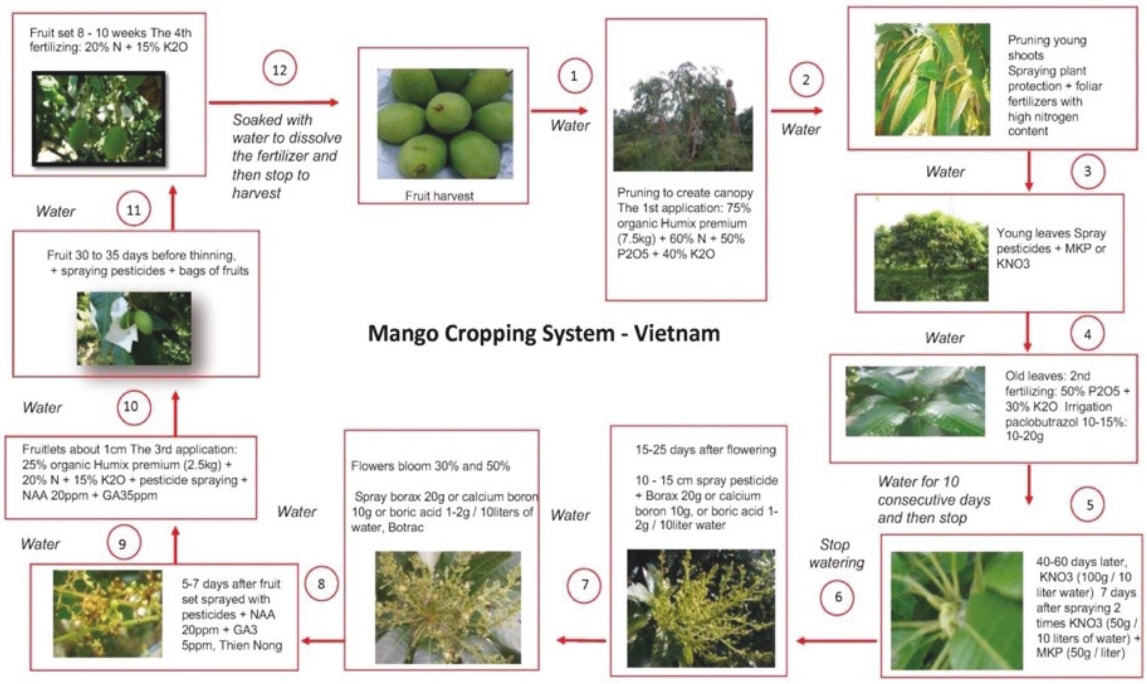

Figure 7.1 Mango management cycle for southern Vietnam

Source: Doan & Nguyen, 2013

Vegetative growth

To renew the canopy and physically manage tree structure, trees are pruned after harvest. To accelerate this process, trees are treated with thiourea to promote bud break and gibberellin to negate the floral inductive effectives of thiourea (Tran, 2009).

Gibberellin synthesis inhibitors

- PBZ is an anti-gibberellin synthesis compound used to assist flowering. It is sold as a powder or suspension at concentrations of 10–25%. Therefore, the level of active ingredient must be specified when making comparisons.
- PBZ is used to assist flowering in the following seasons:
    - On season – Dec to Jan
    - Late crop – Mar to Apr
    - Early crop – Jun to Jul
    - Off season – Sep to Oct.
- The optimum application level of PBZ for Cat Chu and Cat Hoa Loc varieties was 1.5 g ai/m canopy diameter (Tran *et al.,* 2015). At higher and lower doses, the number of fruit and yield per tree reduced.
- *PBZ alternative 1: UCZ* – PBZ is used universally by the world's leading mango-producing countries, including Vietnam and others who trade with the USA. However, PBZ is banned in the USA, Australia, and other countries. It is highly likely that Vietnam will ban both PBZ and thiourea in the next few years. An alternative is uniconazole-P (UCZ), a triazole-like PBZ that affects the same stage of gibberellin synthesis as PBZ and similarly improves yield (Tran *et al.,* 2018). Using UCZ as a foliar spray greatly reduces the amount needed (Lima *et al.,* 2016), but in this work, it was applied to the soil.
- *PBZ alternative 2: ProCal* – prohexadine calcium (ProCal) is another anti-gibberellin synthesis compound. It has been successfully trialled on mangoes in Mexico (Verma *et al.,* 2010). ProCal disintegrates rapidly and is only effective in young shoots. It is unlikely to accumulate in fruit and is thought to break down in

soil within 24 hours. The capacity for ProCal to replace PBZ in mango production systems should be evaluated in southern Vietnam.

Leaf conditioning

Chemicals suggested to accelerate maturation of leaves to make them more responsive to floral inductors include potassium sulfate monoammonium phosphate, ethephon and monopotassium sulfate. There appears to be no quantitative data to support these treatments. However, Tran (2009) has suggested that using a foliar fertiliser low in nitrogen and with elevated levels of potassium and phosphate improved leaf function, but inhibited vegetative flush, in the 4 to 6 weeks before floral induction.

Chemical floral induction

Two successive sprays, one week apart, of either 0.5% thiourea or 3.0% KNO_3 are applied to induce mango flowering. The second spray is applied at a lower concentration. Thiourea was more potent and induced more flowers than KNO_3.

Fruit set and retention

Immature fruit loss is concentrated in the first 20 to 30 days after fruit set in Cat Chu and Cat Hoa Loc mangoes (Tran, 2009). Combining naphthaleneacetic acid (NAA) with gibberellin improves fruit production.

Other production practices and issues

Fruit bagging

The widespread use of paper bags in southern Vietnam farms provides physical barriers against pest infestation (e.g. fruit fly). The fruit is treated with pesticides before bagging, which greatly reduces the need for subsequent pesticide use.

Harvest maturity

The stage of development at which a mango is harvested determines postharvest storage, transport requirements and the characteristics related to the appropriate ripeness for eating. Tran *et al.,* (2015) confirmed that:

- Cat Hoa Loc harvest maturity is 85 days after fruit set (80 days in off-season fruit)
- At this stage, calcium carbide-assisted ripened fruit has a Brix^{o} value of >20^{o} and a characteristic Cat Hoa Loc flavour
- Harvesting fruit at 85 days after fruit set reduced fruit size by 8.6–11.8% depending on the season; harvesting at 80 days reduced fruit size by 13.2%.

Fertiliser use

- There is an in-principal agreement among farmers in southern Vietnam that macronutrients are applied at four stages in the development of mangoes:
    - after harvest and pruning
    - at floral induction and flowering
    - 3 weeks after fruit set
    - 8 weeks after fruit set.
- Half the fertiliser is applied after harvest and pruning, with no nitrogen applied at floral induction and flowering. Only nitrogen and potassium are applied at the third and fourth stages during fruit development.
- Studies presenting the recommended amounts of nitrogen, phosphorous and potassium to achieve maximum yield and fruit quality for the Cat Hoa Loc variety are described fully in the activity report.

- Australian research suggests 1 tonne of mangoes requires the equivalent of 845 g of nitrogen. Assuming comparable nitrogen contents in Vietnamese mangoes, these recommendations indicate inefficient nitrogen use. Note that a trial described in Section 7.1.2 found that the farmers were using up to 10 times more fertiliser than recommended. Other trials identified an underuse of fertiliser. The under and overuse of fertilisers requires further understanding.
- In southern Vietnam, potassium chloride is extensively promoted as a fertiliser. Mangoes are thought to be sensitive to chloride ions, and internationally, potassium chloride is not recommended for use on saline/sodic soil, or where there is a risk of salt irrigation water. Potassium sulfate is preferred for use on mangoes, as it has a minimal effect on soil PH and provides a good source of sulfur.

Pest and disease management

Extensive studies have been undertaken in southern Vietnam targeting major pests (fruit fly, thrips, fruit borers, mango hopper, leaf hopper) and pathogens (anthracnose and black spot canker). These studies recommended trialling control measures and innovative non-chemical-based means to manage these issues, and to understand the threats and cost to farm productivity.

Policy and regulatory environment

The Vietnamese government MARD report 2016–2020, sets out the importance of the development of the mango industry. The report identifies that:

- delivery of hygienic, safe food and production processes should be certified under VietGAP or GlobalGAP
- there is a need to focus on improvements in harvesting, postharvest processing, storage, and transport
- development of infrastructure and transition to regional branding is advocated
- cooperation between industry stakeholders to organise production and deliver mango quality is beneficial.

Government policy advocates replacing thiourea and PBZ, with an emphasis on moving to organic processes, managing soil health and nutrition, and limiting the impact of climate change. Mango bagging is mentioned as a standard to improve postharvest performance. Government directives emphasise the importance of value chains, supported by digital technologies and cooperative processes, to develop a sustainable industry.

Good agricultural production practices for safe vegetables, fruit and tea in Vietnam are administered and acknowledged through the accreditation program VietGAP. The regulator of VietGAP, under the direction of MARD, provides principles and procedures to guide mango farmers and producers on harvest, processing guidelines and safe produce. It also aims to ensure the welfare of supply chain stakeholders and consumers, environmental protection, and the traceability of produce (Decision No. 84/2008/QD-BNN July 28, 2008). The same decree details the inspection criteria and guidelines for VietGAP assessments.

An official Prime Minister's Decision notes several policies to support the development of production, processing, and consumption of safe vegetables and fruit (Decision 107/QD-TTG July 30, 2008). The aim was to have concentrated producing areas that meet the conditions for safe production and processing compliant with VietGAP (or equivalent GAP) for all domestic and export fruit trade.

Cooperatives and farmer groups

Cooperation in production and trade of produce is directed by the state. On 24 June 2002, the Prime Minister issued a Decision (No. 80) encouraging enterprises to sign agricultural produce contracts with producers. More recently, additional model groups, clubs and

cooperatives have emerged, although the established groups are informal with low operating efficiencies, and the number of member farms is small.

The organisation of fruit cooperatives in the Mekong Delta is diverse. Many were established with farmer participation on a voluntary basis, consistent with revised Vietnamese cooperative law. The share contribution also differs depending on the structure of the cooperative. For example, the Cat Hoa Loc Cooperative (Tien Giang) expanded in 2005 to 69 members from across 13 communes; in 2018 it had 88 members. Many traders/customers are approaching cooperatives to purchase fruit, particularly specialty fruit. However, the cooperative is unable to sign trading contracts due to unstable sources of supply. In 2018, many established mango cooperatives in southern Vietnam had limited or no uniform production processes.

Results – Farmer interviews

Production

- Orchards in Dong Thap and Tien Gian are small – less than1.2 ha/farm.
- The cost of production was an average of VND10,000/kg based on the relationship between price and profitability. This supports the preference for off-season production when yields are comparable, but trade price is high.
- Production systems require high levels of inputs, including labour for bagging, harvesting and sprays.
- Farming practices are targeted at maximising production – there is less consideration given to maximising yield to meet market and consumer expectations, for example quality drivers.
- Most farmers funded their production without seeking finance
- Long-term established relationships were important when making trading decisions

Chemical use

- All farmers used PBZ to assist flowering and increase yields.
- Fertiliser inputs appeared to far exceed crop requirements and indicated inefficient use. The importance these high inputs play in the off season is unclear, but they represent an opportunity to reduce input costs.
- The mean number of sprays used to control pests and disease in both provinces were comparable, with approximately eight per crop. Large variations were noted, with some growers reporting 12 to 13 sprays.
- The need for sprays is expected since off-season production occurs during the wet season when an increase in diseases is expected.
- Sprays are applied in a comparatively short period, from floral induction until bagging, which can be as short as 60 to 80 days. This suggests that potential rationalisation and improved spray application methods would be advantageous.
- High levels of soil-applied plant growth regulator are used to prepare trees for flower induction. Most growers were targeting off-season production.

Harvest and yield

- Harvest maturity was noted as 80 to 85 days after full bloom.
- The stage of development precedes the fruit attaining full size, and therefore has yield implications.

Agronomy challenges

- The major agronomy problems were linked to understanding and/or technical knowledge relating to poor weather conditions, pest and disease, fake chemicals and the reliability of the flower manipulation process.

7.1.3 Mango market situation in HCMC and Hanoi

This activity provided an understanding of the current market situation for mango in HCMC and Hanoi. It included a market segmentation analysis and an online consumer usage and attitude study to inform the design of chain interventions. This activity was completed within the first year of the project.

Results – Market assessment

The retail trade for mangoes is broadly categorised into groups:

- appearance – size, skin and shape of mangoes
- quality – sweetness, fragrance and being low in fibre
- production certification (VietGAP, GlobalGAP).

Purchase price

Mango purchase price is influenced by:

- timing – on season or off season
- purchase quantity
- type of suppliers (position in the chain)
- additional trading requirements (for example, if return of sale is offered for damaged mangoes).

Packing and transport

The main packing sizes of mango, when purchasing directly from planting areas, are 20 kg or 40 kg plastic bags. Mangoes purchased from trading companies are packaged in polystyrene boxes with holes. Modern retailers are pushing for recyclable and compostable packaging.

Unrefrigerated trucks are the main transport method, but when quantities are small, motorbikes are used.

Retail sales

The average mango sale price depends on variety, timing (season) and size.

Domestic grocery outlets retail mangoes in plastic bags or fruit gift baskets.

Challenges

Challenges for the mango trade were identified as:

- high quantity and quality fruit losses
- fruit shortage during the off season
- dealing with smallholder farmers direct – preference to engage with packhouses
- higher productivity goals led by farmers resulting in lower quality mangoes
- lack of market information and instruction to farmers and packhouses to align demand requirements with supply
- increasing competition from imported mangoes and other tropical fruits.

Results – Consumer usage and attitude study

An online consumer study (1105 respondents) was conducted to identify mango consumption behaviours in HCMC and Hanoi, understand attitudes towards mangoes and mango purchasing, and investigate consumer preferences and willingness to pay for mangoes.

The key finding from the study was the purchase driver 'ready to eat'. At the retail point of purchase, consumers preferred:

- 'Mangoes ready to eat in 1 to 2 days'
- 'Yellow skin mangoes' – preferred to green as yellow is an indicator of ripeness.

However, retailer views are to limit damage and loss of product – they prefer to sell green. Other findings from the online study are summarised below.

Supply and purchasing

- Mangoes produced in Tien Giang and Dong Thap provinces are supplied mainly to HCMC, with a lower percentage to Hanoi.
- 64% of consumers purchased 1–2 kg of mango per store visit, while 30% purchased 2–3 kg of mango per visit.
- 66% per cent of respondents purchased mangoes at least once a week for home consumption; 27% bought mangoes more than twice a week.
- Nearly 50% sometimes purchased fresh mango for consumption outside the home. This indicates that mango is one of the most popular fresh fruits consumed in Vietnam.

Consumer preferences

- A medium-sized mango (300–500 g) was the most popular.
- A strong, fragrant aroma is the most significant attribute in influencing consumers.
- Taste, freshness, shelf life and zero preservatives were the next most preferred characteristics. Mangoes with a sweet taste and less fibre are also highly desirable.
- Compared to 'no indication of place of origin', origin claims (sticker on mango and product label) indicated that product traceability is another important attribute.

Willingness to pay

- No preservatives (chemical free) is one of the most preferred characteristics. Consumers are *'Willing to pay more for mangoes with a sticker/product label'* noting the characteristic as a purchase driver linked to traceability. Therefore, if stakeholders within the chain are seeking to appeal to consumers in HCMC and Hanoi, the promotion of certification and/or key product characteristics (low or no chemical use, growing locality) should be part of a communication message.
- Price is not the most important attribute influencing purchase – consumers were willing to pay more for optimum quality and food safety standards (VietGAP). VietGAP certification mangoes could obtain a higher premium price of VND20,200/kg compared to products without certification.
- Mangoes with a QR code sticker were traded at a price premium of VND10,550/kg higher than 'no indication of place of origin'.
- Consumers were willing to pay a price premium of VND2,570 and VND9,130/kg for yellow skin mango, compared to green skin and red skin mangoes, respectively. They were also willing to pay a price premium of VND4,760/kg for 'ready-to-eat' mangoes compared with mangoes ready in 3 days or more, respectively.
- Consumers do not generally purchase Vietnamese mangoes online.

7.1.4 Value chains for fresh and processed mango

Results – Fresh mango – Value-chain study

The first aim of this activity was to understand current value chains for fresh mango from farms in Tien Giang and Dong Thap through to HCMC and Hanoi markets. The second

aim was to identify opportunities to improve chain practices. Three packhouses were chosen as the central focus for the project (see Figure 7.2 for an example). This activity was completed in the first year of the project.

Production statistics

- The main varieties grown are Cat Chu (44.5%), Cat Hoa Loc (21.3%), green 'Elephant' (17.6%) and remaining varieties (16.6%), focused in Cao Lanh District and Cao Lanh City.
- The planted area of mango production in Tien Giang was around 4,710 ha, with an estimated output of 106,192 tonnes. This is significantly higher than Dong Thap on a production per ha basis, which is attributed to the mix of fresh and processed mango trade. Most farms are in the Cai Bei and Cai Lay Districts.

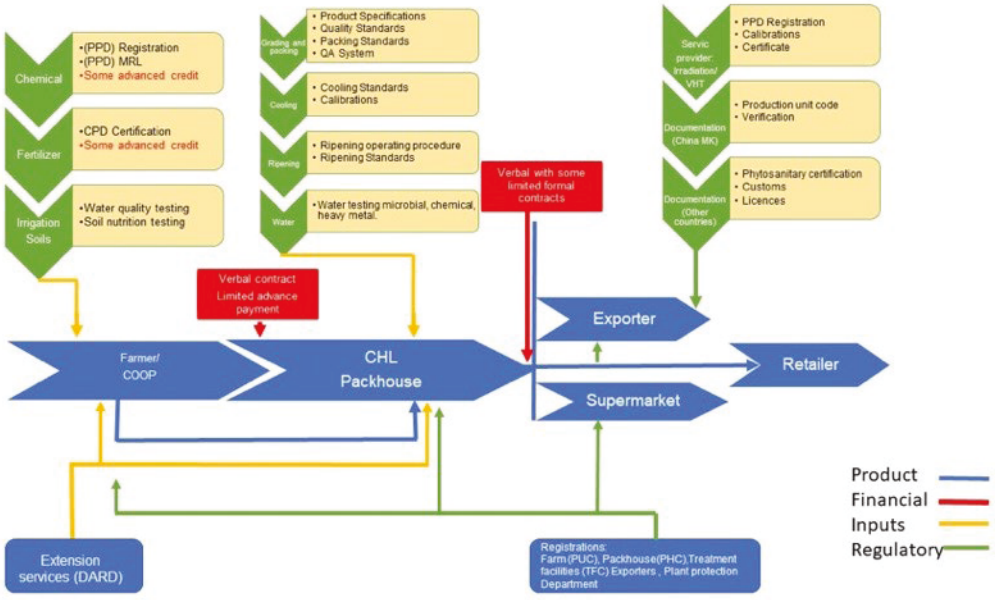

Figure 7.2 Fresh mango value chain, Cat Hoa Loc Packhouse example

Source: Activity analysis

Production issues

- The small size of plantations (average 0.5–1 ha) leads to a fragmented production system. It is difficult to disseminate information, coordinate technological improvements, achieve economy of scale, and for produce markets to execute larger-scale orders. Some of these challenges have been met by organising producers into structures, such as cooperatives or cooperative groups.
- There is a basic level of technical expertise within the identified value chains, although capability is lacking in some places. Agribusiness and trading knowledge for other stakeholders, e.g. packhouse operators, was further advanced.
- There does not appear to be any training on harvesting, postharvest and market information. For example, some farmers did not know where their mangoes were sold and had not been to a modern format retail grocery outlet to see their produce on sale.
- The value chains for all packhouses were traditional in nature. For example, contracts are mostly verbal and long-term relationships are important.
- Credit is not commonly given in advance.

- Farmer expenses and subsequent profitability varied by farm size and variety of mango grown. Profitability between the four seasons revealed a preference to increase off-season production (see Table 7.1).

Table 7.1 Seasonal mango profitability, Dong Thap and Tien Giang farmers

Variety	Early main season (VND per kg)	Peak season (VND per kg)	End of main season (VND per kg)	Off season (VND per kg)
Cat Hoa Loc	47,500	35,000	39,500	65,000 -70,000
Cat Chu	14,000–16,000	9,000–11,000	12,000–13,000	18,000

Source: Activity analysis

- Communication and influence is strong between stakeholders directly up or down the chain. But beyond this first connection, the relationship is limited or non-existent (see Table 7.2).
- Some stakeholders are reluctant to share critical information and perceive sharing as reducing the competitive advantage.

Table 7.2 Value-chain stakeholders relationship overview in southern Vietnam mango trade

Stakeholders	Influence	Comment
Farmers	Low	Generally, short-term arrangements. A small percentage have signed contracts with collectors.
Collectors	Moderate	Mostly have short-term arrangements with packhouses/processors. A small percentage have signed contracts with farmers.
Packhouse	Moderate	Do not always have good control over product inputs or supply. Finance collectors and farmers. Only a small number of mango packhouses are in the region.
Wholesalers	High	Can be disconnected from farmers, and do not always have contracts with collectors. Usually have the best communication networks in the chain.
Retailers	High	Often rely solely on wholesalers for information. Ultimately dictate the finances of the chain, and often will have contractual arrangements with wholesalers.

Source: Activity analysis

- Producers (farmers, collectors, packhouse operators) are very disconnected from wholesalers and retailers, particularly with modern retail operators – the idea of engaging along the chain has not been ‘top of mind’.
- Domestic retailers have little incentive to drive change in traceability, maximum residue levels (MRL), postharvest technology, certifications, or cool chains.
- Large, modern international retailers are starting to request GAP-certified produce, but it is not a mandatory trading requirement. It was not clear how much domestic certified product was available to retailers.
- Retailers are focused on size of fruit rather than skin quality or shelf life. This is leading to poor presentation and high losses. Fruit rot, sap burn, and poor shelf life (exacerbated by the lack of cool chains) are common issues.

Opportunities for research for training and development

- Developing technical training to improve mango quality and shelf life is needed in the form of a ‘Walking the Chain’ activity – see Objective 2.
- *Farm:* An input (fertiliser and pesticide) studies are needed to identify ways to reduce costs at the farm/commune level. This should cover bagging, MRL, harvesting practices, fruit de-sapping, food safety, and developing relationships between stakeholders to improve fruit quality.

- *Packhouse:* A model 'best-practice' set of guidelines from farm to the retail outlet is needed. This should cover extensive postharvest handling procedures to extend shelf life and reduce quality loss along the chain. It should include grading standards, handling procedures, temperature management, packing procedures, fruit transportation, ripening procedures, food safety and certifications.
- This study revealed several opportunities for future research, both short and long-term, to improve fruit quality and benefit the mango trade from southern Vietnam.

Processed mango – Value-chain study

This activity aims to provide an understanding of the current processed mango environment in southern Vietnam, concentrating on mango processing in Tien Giang and Dong Thap provinces. This included a review of studies related to processing and training for local researchers to undertake 20 semi-structured interviews. The interviews covered, but were not limited to, production practices, seasonality, cost impacts, yield and environmental issues.

Results – published studies and interviews

- Processors reported a range of percentages for processed mango. Much of the processing is informal and not captured in annual statistics. However, in general, around 30% of mangoes produced in Vietnam are thought to be used for processing. Most mango is consumed fresh and supplied to traditional and modern retail formats.
- Industrial fruit processing is spread across the country, with 71 registered enterprises in northern provinces and 56 in the south.
- Mango processing is shared between state-owned entities, local small firms and foreign investment companies.
- On average, processors reported that an enterprise produces around 500,000 tonnes of processed products per year. This is mostly concentrated fruit juice and canned fruit account, with dried fruit, soft drinks and instant quick freeze products making up the remainder.
- Processed products are mainly exported, with limited domestic trade.
- In the last 10 years, the average consumption of processed foods has increased yearly (food – 9.68% and beverages – 6.66%).
- The main cultivar used for processing is Cat Chu. Others include Keo and green skin mangoes – supply fluctuates significantly during the year.
- The main season is March to May, when supply is plentiful, and price is low. When there are supply gaps, fruit is often sourced from Cambodia.
- The average annual labour force in processing companies is 130 staff/enterprise. State-owned enterprises tended to employ more – 160 staff/enterprise, with foreign enterprises engaging 90 staff.
- Vietnam Government has endorsed 12 fruits in the national *Fruit Processing Priority Program*, including mango.
- Investment in food and fruit processing in Vietnam is attractive, with multiple tax incentives relating to increasing production volumes and exports.
- Wastage is a major issue. Processors noted 12 to 30 tonnes/day of discarded mango when product did not meet specifications.
- Mangoes are often graded twice – at the farm and again at the packhouse, within a range of grading criteria. Typically, Grade 2 mangoes are supplied for processing.

- Freezing mango was confirmed as the most appropriate technical method to use significant volumes of fruit, and thus became the focus of A2.4 in Objective 2 ('Establish a partial processing trial as a methodology for mango season extension and productivity improvement').

7.1.5 Factors affecting mango quality benchmarks

This activity involved an in-market observation study of the fresh mango value chain, covering on-farm, market stalls, and speciality and high-end retail stores. It also supplemented the understanding gained from qualitative interviews with buyers to capture quality issues related to price and sales volumes.

Results

Key critical control points identified for assessing mango quality and losses included on-farm, packhouse and retail points of sale in HCMC and Hanoi.

Cultivation practices and common types of loss

- Cultivation practices in Dong Thap and Tien Giang occur over 90 days (Figure 7.3).
- Mango quality is strongly affected at the stage of fruit set, young fruit, fruit bagging and harvesting stages.
- Losses are due to sap burn, pest/insect damage, abrasion, small and undersized fruit, over-ripeness and physiological disorders (e.g. jelly/cavity/soft nose flesh).

Postharvest losses of Cat Chu and Cat Hoa Loc mango

- On-farm, the main reasons for postharvest losses are sap burn and insect damage. Other causes are abrasion, over-ripeness and small fruit.
- At the packhouse, overripe fruit and sap burn are the main reasons for postharvest losses. The significantly high level of sap burn indicates harvesting and transportation problems.

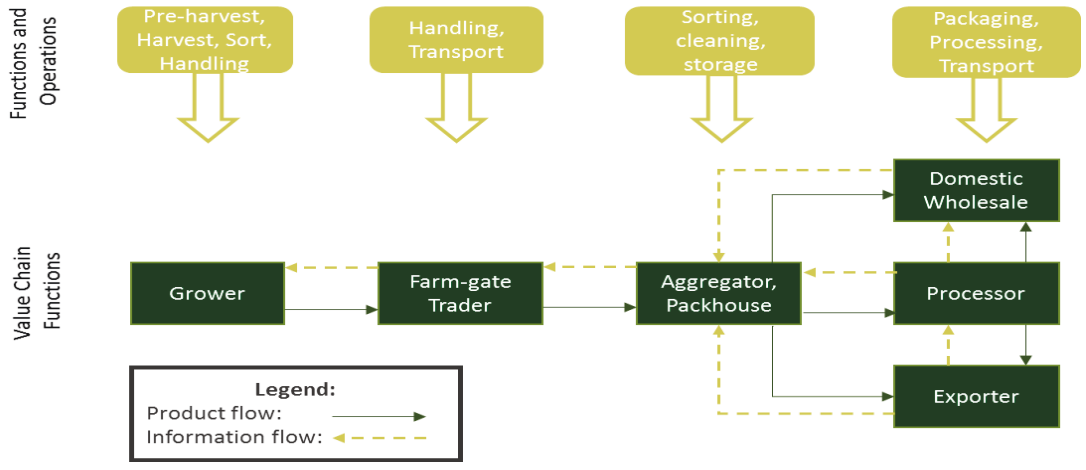

Figure 7.3 Processed mango value chain, southern Vietnam

Source: Activity analysis

Retail point-of-sale issues for Cat Hoa Loc mango

- Most retail chains have no refrigeration and are set up for the quick movement of fruit, with small volumes supplied regularly.
- Almost no fruit is sold at eating ripeness at the retail level. This indicates there may be problems with bringing the fruit to this stage (e.g. losses from dehydration, disease or local behaviours). Or it is culturally not sold at a 'ready-to-eat' maturity stage. This severely limits how much fruit is sold, as it eliminates the impulse buyer.
- Dehydration and immature fruit seem commonplace in most retail outlets.
- Disease was evident on fruit in store, indicating slow turnover of fruit.
- Fruit on sale in retail outlets appeared to be Grade 2.

7.1.6 Case study of mango exports

This study was conducted in Year 1 and was to focus on the market of Hong Kong. Due to the pandemic, the focus changed to:

- capturing other export market information
- assisting the release of new Australian mango varieties
- understanding the European Union export market for counter-seasonal trade of mangoes from Australia.

Results – Stage 1 Hong Kong market interviews and observations

Trading and origin of mangos

- HK is a non-protocol market with limited import restrictions for mangoes, thus many mangoes from the region are imported.
- Trading relationships are long-term and well established.
- Australia has been trading mangoes with HK since the 1980s.
- Mangoes are sold by 'piece' (individual fruit or combo of two to four fruits).
- During the peak season (northern hemisphere summer), Philippine mangoes dominate the market. During winter (Nov to Jan) Australian mangoes are the dominant variety by volume. Vietnamese mangoes are rarely traded and often not recognised by consumers or retailers.

Pricing classification and labelling

- Mango prices are classified into the following groups:
    - traditional wet markets (lowest price)
    - retail grocery outlets (medium/high price)
    - high-end supermarkets and department stores (premium quality, highest price)
    - mangoes traded for bakery and confectionery use are often inexpensive and external blemishes or marks are ignored.
- Mangoes are sold labelled and unlabelled (mainly in wet markets)
- Labelled mangoes are 'stickered' with country of origin and variety/branding – e.g. Australian Calypso or Kensington Pride

Display and consumer preferences

- Retailers display their mangoes on shelves with no packages or boxes. In addition to fresh mango, some supermarkets and department stores retailed cut mango with other tropical fruits. This was largely to service the 'out-of-home' consumption trade.

- Although consumers usually prefer to purchase ready-to-eat mangoes, this was only seen in the premium category of mangoes. For mid-range priced mango, retailers preferred to offer green mangoes.
- Australian mangoes (Nov to Feb) are well received and available during Christmas and Lunar New Year celebrations.

Other considerations

- As a re-export hub, HK is still operating using informal trade links – this was not something accessible to study at the time.

Results – European Union study

Consumption and demand

- Mango consumption in the European Union is rising, despite difficulties in sourcing and the preference for local seasonal fruit.
- Germany, the UK and France are the leading markets for imported mangos.
- Kent and Keitt varieties are preferred from Brazil, Peru and northern Africa.
- Demand is increasing for ripened and fresh cut mangoes.

Import requirements

- Attention must be paid to MRL import requirements relating to pesticides and other contaminants.
- Imported mangoes require a phytosanitary certification from the country of export.
- HWT is required from the point of export.

Consumer preferences

- The top three attributes that influence mango purchase are flesh texture (mouthfeel), sweetness and ripeness. In the UK and Germany, consumers also regard juiciness as important.
- The top three extrinsic mango attributes are chemical-free claims, price and food safety certification. Consumers have food safety concerns about imported mangoes from Vietnam (34%) and Australia (18%).
- 75% of consumers preferred medium-sized mangoes (350–550 g), while 21% of UK consumers preferred larger mangoes (550–800 g).
- Most mangoes were purchased in a twin pack.
- More than half of consumers knew their mangoes came from Brazil, Peru, Spain, Vietnam, and Australia (respectively, the proportion sold from these countries was 28%, 21%, 19%, 12% and 5%). Just under half of respondents (45%) did not know the country of origin of their purchased mangoes.

Summary

- Certifications (chemical free, food safe, fair trade) are needed to export mangoes to the UK and European Union to serve premium imported fruit retailers.
- The initial focus should be on medium-sized varieties, appropriate ripeness and twin-sized packaging.

7.1.7 Wholesale market monitoring in HCMC and Hanoi

This study aimed to capture and track mango information from three wholesale markets by collecting weekly mango pricing and trading information from 20 wholesalers (10 from Thu Duc market and five from Binh Dien market in HCMC, and five from Long Bien market in Hanoi) between March 2020 and June 2021.

Results – market insights and pricing

Mango trading in wholesale markets

- Cat Hoa Loc mango is the most popular variety in the southern wholesale market.
- Long Bien, Binh Dien and Thu Duc wholesalers sell more mango varieties than other wholesalers.
- Weight is the main criterion for grading mangoes.
- Most mangoes in the wholesale markets were grown domestically in Cao Lanh City and District, Dong Thap province.
- Mangoes at Thu Duc market are sourced from western, eastern and south-central coast provinces, while mangoes at Binh Dien market are predominantly from western provinces. Southern mangoes available at Long Bien market are from Dong Thap (transported to the market by trucks without cold storage).
- Compared with other markets, mango supply in Thu Duc wholesale market is sourced from many provinces, providing year-round trade.
- Long Bien wholesalers did not appear to trade the Cat Hoa Loc variety in the north of Vietnam.
- The majority of green Keo mangoes are imported from Cambodia.
- Collectors are the main mango suppliers to wholesale markets, while vendors and stalls in wet markets are the main buyers.
- Wholesale markets also sell their products directly to consumer groups and the food service channel.

Mango pricing in wholesale markets

- Cat Hoa Loc is the premium priced variety sold in the wholesale market.
- Mangoes are sold at higher price points in the off season compared with the main and shoulder season.
- Prices generally peak in December and January and bottom out by March.
- Due to transportation costs from the southern provinces to the north, prices at Long Bien market (Hanoi) are higher than in the southern wholesale markets.
- In both north and south wholesale markets, the effects of the pandemic caused Cat Chu and Cambodian Keo prices to stay higher in the post COVID-19 period of this study.

7.2 Objective 2

The studies in Objective 2 focused on the design, development and implementation of 'proof-of-concept' interventions based on the learnings gained from the activities of Objective 1. As already noted, the break in research caused by the pandemic brought limitations for some of these activities.

The interventions sought to improve productivity and fruit outcomes on-farm, postharvest, retail and processor points in the value chain. Examples discussed below include fertiliser management, treating sap burn and using HWT to improve quality, freezing mango to save waste, and looking at different ways to display mangoes for sale.

Activity reports presenting the full studies are available on the project weblink.

7.2.1 Fruit productivity and quality improvements through on-farm interventions

This activity examined three interventions:

- disease management (anthracnose and black spot disease) and comparison of best practice against current industry practice to identify on-farm practice change
- fertiliser management (nitrogen, phosphorus and potassium (NPK) dosage)
- identification of casual agents of disease and a HWT study to control or suppress disease.

Results – Best-practice disease and pest management

Part 1 – Intervention evaluation of chemical control strategies in mango

The aim was to evaluate different chemical control strategies to suppress disease development in bagged fruit, and to control bacterial black spot and anthracnose. The strategies were developed from the current list of MARD-registered products for mango.

The results indicate that:

- Fruit bagging can reduce disease incidence and severity.
- Bacterial blackspot can be significantly reduced by combined chemical treatments, such adding the antibiotic oxytetracycline hydrochloride.
- Anthracnose can be best treated using propiconazole plus difenoconazole, although all treatments significantly reduced the level of disease, including the reduction of inoculum on flowers.
- In a commercial spray program, resistance can be better managed by changing chemical groups between systemic fungicide spray applications.
- Some farmers use a calcium/boron additive that is anecdotally reported to reduce fruit drop from anthracnose infection. However, from the data analysis in the trials, it is not possible to draw any conclusions on this.

Part 2 – Intervention evaluation of best-practice management against industry practice

The aim was to evaluate best-practice pest, disease and cultural management against current industry practice; measure productivity, effectiveness and benefits; and evaluate the impact of fruit bagging on MRL. The evaluation was carried out on a demonstration farm and a control farm. The demonstration farm followed integrated pest management and cultivation guidelines for Vietnam, while the control farm used the farmers' current practices.

The results indicate that:

- A significant production cost saving and improved returns per hectare were noted in the demonstration farm, indicating there are significant benefits to be gained by practice change.

- Fruit bagging can significantly reduce pesticide levels in the fruit, to undetectable levels in many cases.
- Fruit bagging reduces MRL, even in farms that are following poor pesticide management practices.

Results – Fertiliser management on Cat Chu & Cat Hoa Loc mango varieties

Fertiliser overuse is common in the Mekong River Delta. This can affect fruit quality, disease susceptibility and environmental pollution, while not necessarily increasing yield. The aim was to determine the optimal NPK fertiliser dosage for Cat Chu and Cat Hoa Loc mango production in terms of yield and fruit quality.

Part 1 – Cat Chu mango intervention

Four different dosages were tested. The results revealed that:

- NPK dosage significantly affects fruit weight, fruit length, fruit width, yield, edible portion, flesh thickness, but not fruit diameter, brix content, peel or flesh colour, or the total number of fruit per tree.
- Yield can be maintained with lower applications of NPK than those currently applied.

Part 2 – Cat Hoa Loc mango intervention

- NPK dosage affects fruit length and yield per tree, and to a lesser extent fruit quality factors such as edible portion, pulp thickness, brix content and colour of pulp.
- As in the Cat Chu study, NPK doses had no effect on the total number of fruits per tree, fruit weight, fruit diameter, fruit width and colour of peel.
- Lower dosages did not significantly affect the yield parameters of weight and fruit size, indicating that yield can be maintained with lower applications of NPK than those currently applied.

Results – Hot water treatment study – Vietnam

The aim of this intervention was twofold:

1. to identify the causal agents of postharvest disease in mangoes from southern Vietnam

2. to examine the effect of HWT and chitosan coating for delaying or suppressing postharvest disease. (Chitosan is a biopolymer with antibacterial/fungal properties that can control or suppress disease development in many agricultural products.)

The results revealed that:

- The dominant causal agent of postharvest rots was the fungus *Colletotrichum sp*. for both Cat Chu and Cat Hoa Loc varieties.
- HWT of 53ºC for 5 minutes reduced the level of post-harvest rots. This would be suitable for disease suppression in fruit sold in short or medium-distance markets, but not for long distances, which might require fungicide use.
- Chitosan coatings reduced moisture loss and disease levels of disease over short storage periods (less than 2 weeks), but not over longer durations.

Results – Hot water treatment study – Australia

Heat treatment of mangoes to meet phytosanitary requirements has become the industry standard since the restrictions on fumigants. HWT and vapour heat treatment protocols allow Australian mangoes to access the Chinese market (MICoR, 2016). The requirements are either a core temperature of 46ºC for 20 min or 47ºC for 15 min (Johnson & Duthie, 2018).

Trials of two varieties (NMBP-4069 and R2E2) examined two preconditioning treatments of 6 and 24 hours, followed by HWT at 46°C for 20 min and 47°C for 15 min. The results showed that:

- NMBP-4069 was more versatile, with two preconditioning treatments responding well – 6 hours at 34.8°C, and 24 hours at 34.8°C.
- R2E2 also performed well under preconditioning at 42°C for 6 hours.

Note – full results have been withheld pending the acceptance and publication of a scientific research paper.

7.2.2 Expanding seasonal flowering

This study aimed to determine whether the GA synthesis inhibitors UCZ or ProCal can replace PBZ, pending its removal as an approved chemical in Vietnam. PBZ is currently used to manipulate flowering and synchronise harvest maturity. The study compared the growth responses of Cat Hoa Loc trees treated with the standard Vietnamese soil-applied PBZ at the standard time of induction, with trees treated with foliar applications of UCZ or ProCal.

Results – On-farm interventions

Due to restrictions during the pandemic, the study was undertaken on the SOFRI research orchard using 5-year-old Cat Hoa Loc trees. The results showed that:

- Flowering and fruit production was observed in all treatments. However, there was little or no yield in almost half the trees of each treatment.
- There were some high-yielding trees in the ProCal treatment group, which also appeared larger than the trees in the other treatments.
- The trees in the UCZ and ProCal treatments appeared to have a premature vegetative flush that could have reduced their flowering and yield by inhibiting flower induction.
- Use of potassium sulfate sprays in the period between treatments, and treatment for floral induction, may assist in preventing premature bud growth.
- The minimum temperatures recorded were higher than those thought to induce flowering in other mango cultivars. This suggests that the chemical treatments applied caused the responses observed but would be more conclusive if temperature records were maintained for the entire trial.

7.2.3 Mango productivity and quality improvements in fresh supply chains

This study aimed to identify and demonstrate opportunities through proof-of-concept interventions to improve productivity and quality in fresh mango supply chains. Interventions tested in demonstration formats included sap management, HWT (see activity A2.1), on-farm electronic trolleys to aid sap management, and a full demonstration chain intervention associated with mango quality metrics.

Results – Sap management intervention

Sap or latex burn is a leading cause of quality loss in mango in Vietnam. The acidic nature of the sap will cause a burn if it encounters the skin of the fruit. This is not always apparent immediately and will often develop over time as the fruit moves through the supply chain. Most of the damage by sap occurs in the early stages of the supply chain: on-farm at harvest, and during transportation to the packhouse.

Sap management techniques exposing the fruit to high-pH solutions to neutralise the pH of the sap. This is currently undertaken at the packhouse, meaning the fruit has already been exposed to sap and breakdown and degrading of fruit quality has already started since harvest.

A 2021 study of sap management indicated farm-level interventions could reduce damage and thus maintain fruit quality through to the packhouse and retail sales points. To verify these results trials were repeated at four farm sites in Tien Giang and Dong Thap provinces to compare sap treatment at the farm, collector, and wholesaler points in the chain.

The results revealed that:

- Sap-burn impact was significantly lower through the chain with the de-sapping treatment.
- Overall, sap-burn levels were considered minor with most sites recording low levels.
- Farms recorded low levels of sap, as expected, as the burn does not appear for several days after picking. This was evident from the higher levels recorded at the packhouse and the wholesaler.
- High levels of standard error were seen in the results, suggesting large variations in the data recorded at each site. This could be due to small sampling size or prior level of damage before treatment due to poor harvesting practices.
- Some sap-burn levels were recorded as lower at the wholesaler/retailer, which might suggest that some grading has occurred at the packhouse stage.

Electronic bin trolley to aid sap management on-farm

The mango farming and handling processes at Vietnamese packhouses and trading companies is not efficient. After harvesting, mangoes are collected, de-stemmed and de-sapped immediately (from 1 to 5 minutes) to ensure premium fruit are packed for sale. Sap burn causes postharvest losses for farmers and traders.

Currently, Vietnamese studies on mango treatment methods are limited. Some companies and mango packhouses in Long An and Dong Thap have been applying de-sapping treatments, but it takes a long time for mangoes to travel from the farm to the packhouse.

A mobile mango de-sapping treatment device at the farm level would help reduce sap burn and improve the value of mangoes in the supply chain. This concept development and study of this specialised device validated the use of and the requirements for de-sapping on farms suitable for the soil and terrain of Vietnamese mango farms.

The results of the trolley trial showed that:

- The trolley resolved issues of onsite potable water availability and ability to move operations around the orchard efficiently, and also proved to be time efficient.
- Reductions in sap damage can reach 90% at packhouse level, and 94% at retail level.
- The practicality of sap management at farm level was confirmed.

This study has not been commercialised, as it would be expensive to implement. The application and long-term benefits to the agricultural sector needs to be further explored to confirm the economic rationale for this piece of equipment.

Results – demonstration chain intervention

The trial demonstration chain focused on interventions relating to sap management, HWT of mangoes, and retail packaging (mangoes supplied in six-pack cartons). The aim was to improve shelf life and overall quality of fruit, thus allowing farmers, packhouses, vendors and retailers to command a higher price.

The trial revealed that:

- Sap-burn and hot-water-treated mango fruit supplied in six-pack cartons were an attractive proposition to consumers.
- HWT was only partially successful in suppressing disease.

Other insights included:

- Fungicidal treatment could be used in conjunction with the HWT to boost the ability to suppress disease.
- Fruit quality (including disease control) is important in gaining price premiums and attaining consumer and retail sector confidence in the fruit.

There were disparities in the benefits gained from the retail sale of treated fruit among the different value-chain stakeholders. The following are some contributing factors:

- A shortage of premium-grade fruit on-farm resulted in some fruit supplied being riper than normally desirable.
- Delays in undertaking the trial meant the study was undertaken in the mango growing off season, exacerbating fruit shortages.
- The research study's prices offered to farmers were 'sight unseen' and may have been artificially inflated, but this is unknown.
- On average, only 32.3% of harvested fruit were of suitable premium quality for treatment and to supply to supermarkets.
- The retailer achieved the highest sale margin, at 31.6%. The packhouse and vendor would have made a financial loss, once all the costs of mango treatment, supply of six-pack cartons, transportation and other overheads were taken into consideration. Further understanding of costs in real time is needed.
- The retail price per kilogram of treated Cat Hoa Loc mangoes was almost double the price of the untreated.

The intervention trial successfully demonstrated the potential benefits of sap-burn management and HWT of mangoes. Despite some limitations, the progress and acceptance of the treatment procedures by all value chain stakeholders is encouraging, having signaled a commitment to continue the practices post-trial. This is confirmation/validation of the proof-of-concept outcome.

7.2.4 Mango productivity and quality improvements in processed supply chains

This study aimed to establish a partial processing (freezing) trial to extend the mango season extension and improve productivity. To support this study, a Code of Practice for the mango freezing technique was developed, as well as a guide on Recommended Procedure to help processors undertake freezing in a commercially viable way.

Results – Freezing trial study

The study showed that:

- Mangoes can be frozen stone-in or as flesh alone without reducing flavour, aroma, appearance and overall acceptability.
- Bulk frozen mangoes could be simply peeled and frozen for later stone removal by mechanical means. This system would make lesser demand on resources when mangoes are at peak supply.
- There is less of an imperative to purchase high grade mangoes (1 and 2) for this procedure. The lowest grade mangoes were used for the trial.
- Standards varied among processors and are reflected the price paid for mangoes.
- The costs and return for frozen mango stored for 1, 2 and 3 months are given in the final report. Full production expenditures including input materials, handling, ripening treatment, cleaning materials, sterilisation, packaging, and energy costs were identified.
- The average profit ranges from AUD38,289 to AUD46,441/100 tonne of frozen product.

Many intangible factors remain unanswered from this trial. These can only be defined from a full-scale commercial production run. However, there is sufficient data to support the attractiveness of the freezing system to existing manufacturers and to aspiring processors.

Results – Code of Practice guide

- The Code of Practice applies to the receiving, preparation, processing, handling, storage, transport, distribution and retailing of frozen mango.
- The objective of the Code is to guide the handling and managing of frozen mangoes to help ensure product safety and the manufacturing processes for the products. This includes quality parameters, composition and labelling.
- To the team's knowledge, this guide is the first for frozen mango in Vietnam to emphasise proper cold chain management, incorporate good hygiene and good manufacturing practices, and apply hazards and critical control points.

Results – Recommended Procedure guide

The Recommended Procedure guide helps existing processors to accommodate a large influx of mangoes at the height of the season. It also helps intended processors who are yet to invest in technical free-flow equipment. Adoption of bulk partial processing will enable enterprises to make greater use of mango, reduce waste and improve return for effort for all stakeholders, especially smallholder farmers.

Examples from the guide for recommended procedures include:

- Traceability documentation is required to maintain a Hazards and Critical Control Points (HACCP)-accredited processing enterprise – for example, the origin of the fruit and harvest processes, farm certifications and transport documentation.
- Chemical treatments either on-farm or during transport to the processing facility must be recorded and given to the processor.
- Rejection registers should be maintained, including reason and image records.
- Fruit should be washed with a decontaminating solution before being taken into a HACCP or ISO-compliant processing area.
- Batch sizes should correlate to individual frozen product items – e.g. for individual retail sale or an ingredient (batched) for value-added processing.
- CODEX-directed processes require all products to be stored at –18°C.
- Storage and packaging direct the use of a polypropylene barrier, either biaxially orientated or laminated with polyvinylidene chloride, to help extend shelf life.

7.2.5 Research analysis and validation

The activity aimed to undertake financial, economic, and business feasibility analysis on the trial interventions. It evaluated three trials in the areas of fertiliser use, flowering treatments, and sap burn. Following the departure of the nominated researcher, the activity was undertaken by a new in-country Vietnamese researcher, with support from the lead Australian researcher provided via online discussions. The research team faced logistical challenges such as poor internet connectivity, no prior experience with this type of activity and lack of willingness by farmers to participate, while managing travel restrictions due to post-pandemic protocols.

Results – Analysis and validation

Limitations

For the evaluation studies on fertiliser, flowering and sap burn, a selection of private sector farmers/operators was made largely based on opportunity (access), rather than location. Note that the researchers conducted standalone experiments. This presents a

different perspective and in some cases contrasts with the intervention findings (and their original purpose using a whole-of-chain lens) in the activities A2.1, A2.2 and A2.3.

Further, the understanding of validation was misinterpreted and is noted as an area for future training and development. Consequently, the assessment does not fully meet the activity aims and provides limited validation.

For example, the aims of the:

- **fertiliser study** (see also Section 7.2.1) focused on overuse of fertilisers causing poor crop nutrition and providing training to implement practice change to improve fruit quality and reduce disease susceptibility and environmental pollution. However, this was not considered in this evaluation.
- **flowering study** (see also Section 7.2.2) were to identify improvements in flowering practices, particularly in the case of identifying a suitable replacement for PBZ. Inconclusive results were obtained due to factors such as small sample size, crop failures and unfavourable weather conditions.
- **sap-burn study** (see also Section 7.2.3) were to improve mango quality loss by using a high-pH wash to neutralise the pH of the sap immediately after harvest for longer distance chains (e.g. Hanoi and exports). Sap burn is the leading cause of quality loss and occurs over time after harvest. It cannot be measured using only one point in the chain.

As these deviations were noted after the trials had been completed, it was too late to repeat the activity. The outcomes for this activity as undertaken are summarised below.

Results – Fertiliser evaluation

- The results in each growth stage were compared between the control and experimental plants. For both Cat Chu and Cat Hoa Loc mangoes, the evaluation demonstrated no difference in dormancy between the control (including the experiment and neighbouring households) and the project intervention.
- *Flowering stage* – the project's experimental formula had a stronger effect on Cat Hoa Loc mango, which obtained a flowering level 15 to 25% higher than traditional cultivation; it had a weaker effect on Cat Chu mango, which had a flowering level of around 5% lower.
- *Fruit development* – there was an inverse relationship between the two mango varieties. The number of young fruit in the project's fertiliser formula was 10% higher than that of the conventional practice of Cat Chu mango; whereas the young fruit level of Cat Hoa Loc mango decreased by 5 to 10%. However, at the harvesting stage, Cat Chu mango under intervention produced more uniform and larger fruit than the control group.
- *Fruiting rates* – (amount of fruit/number of flowers) were similar between the treated and conventional practices.
- *Grade of fruit* – For Cat Hoa Loc mango, fertilising increased the rate of grade 1 (>500 g/fruit) to around 15 to 40% higher than traditional farming; grade 2 (400 to 500 g) increased only slightly, at 5% higher than the control.
- *Yield* – In the Tet season (Lunar New Year), 28 out of 40 trees under project treatment had 14.8% higher yield than control trees. However, this yield only increased by 1.3% when considering all trees (fruited and non-fruited). According to farmers, calculating additional yields based on individual trees is a more accurate, given each tree has its own fruit cycle.
- *Yield predictions* – Farmers had not yet harvested at the time of the second survey in February 2022, but one farmer claimed that the fruit size of the current season, under the project treatment was uniformly larger than that under the conventional

practice – predicting that the grade 1 percentage would be higher than 40% as observed in the last season, possibly up to 50 to 55%. In relation to yield, he further predicted a 44.3% increase in mango yield under the project intervention. This prediction needs to be verified in the next harvest the following year.

- Another farmer had no clear prediction about the fruit grade or discrepancies between treated and untreated mango trees. The difference, according to households engaged in the project, was due to:
    - the application of fertilisers using the new (SOFRI) formula based on testing soil samples, thereby knowing the lack and excess of trace elements in the soil, which is the foundation for fertilising with balanced nutrition as recommended by the project. In the traditional method of fertilising, the soil samples were not tested; participants (farmers) relied solely on their own experience.
    - perceptions of organic fertilisers and manure for plants shifting significantly in recent years, resulting in an increased use of organic fertilisers and manure. This fundamental change causes the mango trees to grow more naturally, ensures the quality of fruit, and reduces soil erosion. To minimise costs, all farmers stated they would reduce non-organic and increase organic applications.

Results – Flowering evaluation

- There was no difference between the project's flowering treatment formula and the traditional flowering treatment, with respect to the dormancy period for both mango varieties. Only one household cultivating Cat Chu observed 12.5% more flower proliferation.
- Treating Cat Chu mango with UCZ and Prohexadine resulted in 10 out of 16 experimental trees developing fruit (62.5%); in the control treatment (PBZ) there were 10 out of a total 29 trees, accounting for 35% (3 out of 8 trees produced fruit under the control experiment).
- For Cat Hoa Loc mango, some trees under the project treatment did not produce flowers and fruit, while traditional farming showed about a 10% reduction in fruit set for flowering plants.
- The flowering experiments in this evaluation have not been satisfactory and were limited. The flower treatment process encountered unfavourable weather (early and repeated rains), causing the experiment to be repeated, thereby reducing the accuracy. Further, according to one farmer, the Cat Hoa Loc mangoes failed this year, making it difficult to compare between trees in the orchard and those from previous years. Weather affects flowering, and it is considered a crop loss if it rains for 3 to 4 consecutive days during this period.

Results – Sap-burn evaluation

Two treatments were prepared for this experiment:

- *Traditional (control) treatment* – Famers removed pedicels (3 to 5 cm long), cleaned off the sap of fruits before packing them into baskets (20 to 30 kg each) and then delivered them to local buyers.
- *Project treatment* – Picked mangoes were cleaned and pedicels were cut. The fruit was weighed, soaked in cold and clean water for 10 to 15 minutes, dipped in SIAEP 1 solution (2.5 g/litre) for 1 minute, taken out and dried.

One difference between the experiment and the control was that mangoes were stored for longer than 1 to 2 days at room temperature (Cai Be fruit shop in Cai Be district), while the temperature in the supermarket (WinMart) was set by air-conditioning. Because the

project-treated mango had a more attractive appearance, it sold faster in the supermarket than traditionally treated mango. This makes it difficult to determine the exact solution concentration required to extend the ripening time by 1 to 2 days. Observations also revealed that after dipping mango and drying at the farm gate, the ripening stage was slower than wrapping mango with paper.

Mangoes treated under the project method differed from traditional treatment in that they had been washed, including any sap attached to the skin. Farmers believed that the chemical could dissolve and clean the mango sap in the treatment solution.

7.3 Objective 3

Objective 3 focused on communication and stakeholder engagement, building links between stakeholders, disseminating and communicating project findings and building capacity of Vietnamese researchers.

7.3.1 Stakeholder engagement

Project leaders from each institute met in the first year to formulate the role of the reference group, meeting criteria and time schedules. The team identified and established a multi-stakeholder mango reference group with representation from policy makers, farmer grower groups/packhouses, processors and traders.

In addition to the Directors of SIAEP, SOFRI and SCAP, representatives included:

- Vice Director, DARD, Dong Thap province
- Director, Centre of Extension and Agriculture Services, Tien Giang province
- Professor, Can Tho University, Agricultural Sciences
- Vice Director, Department of Science and Technology
- Director, Long Uyen Co, fruit processing company
- Vice Director, Vina T&T, import Export Trading Service
- Director, Kim Nhung Packhouse, Dong Thap province
- Director, Ba Xoai Packhouse
- General Secretary, Vietnam Fruit Association.

The purpose of the reference group was to share ideas related to the project's development, and seek input and engagement in the research activities. The three project objectives were used as the Terms of Reference to guide the group.

The reference group was formed and met in Cao Lanh City, August 2019. This meeting discussed a range of topics, such as production, value chains, market situation, provincial situation and current priorities. It also covered proposed activities linked to the pilot interventions. The Vietnamese in-country partner shared a record of the meeting with project team members.

The reference group was scheduled to meet again in May 2020 but was interrupted by restrictions imposed by the pandemic. After returning from the enforced travel bans in the final year of the project, the reference group and additional industry stakeholders engaged in several in-field and onsite discussions with in-country researchers.

Most of the project team reconnected with reference group members and other key chain stakeholders in the project's final year (2021–2022). Selection and confirmation of the pilot interventions undertaken in Objective 2 were discussed with input from several reference group members (public and private sector).

The next steps, as presented in this report's Recommendations (Section 9.2), have been proposed by the reference group members, stakeholders from the intervention activities and project team researchers.

7.3.2 Stakeholder linkages and communication

To facilitate stakeholder linkages and communication, the project team agreed to implement a central website as the focal point for document storage and sharing on an open-access platform. The resulting website, www.vietnammangonet.org, became the hub for the project, allowing stakeholders to communicate, interact and engage, as well as build trust and share information. The site gave the in-country partners local, culturally appropriate versions of information to use, giving them more of a voice in the project.

Four annual workshops were planned, with agendas and timetables published on the website. Objectives agreed outputs and milestones to be achieved each year were documented. The project's research team, activity leads, and external stakeholders developed the plans. Draft plans were shared with the team before each workshop.

Three annual ACIAR reports were prepared (2019, 2020 and 2021) and submitted. Unfortunately, the pandemic and the subsequent travel restrictions meant that in-person workshops with research team members and chain stakeholders was suspended for a period of the project. Consequently, not all evaluations were completed.

The stakeholders who benefited from the linkages in the project were:

- researchers from the partner institutes – SIAEP, SOFRI and SCAP
- Australian research leads
- cooperatives, packhouse operators and processors
- traders, retailers and other supply chain stakeholders
- DARD – district level engagement with farmers, collectors, packhouses and cooperatives.

7.3.3 Linkage building through workshops and meetings

During the first 18 months of the project, the team delivered many workshops and meetings (in-person and online). These events contributed to initiating and establishing relationships and starting the linkage-building process for team members.

The events included:

- 21+ workshops and meetings between September 2018 and June 2019–2021
- 70+ workshops, meetings, and virtual training sessions between (during and post the pandemic lockdown periods) July 2019 to Jun 2020.

Due to interruptions from the pandemic, workshop-based intervention activities were not undertaken until the last year of the project. The 2021–2022 interventions focused on two key areas: on-farm and within a demonstration chain. Participants were chosen based on their engagement at key points in the supply chain and included farmers, collectors, packhouse operators, cooperatives, wholesalers, and retailers.

The workshops incorporated bespoke skill-building, using traditional and digital methods. Information was shared in Vietnamese and English formats, and facilitators for workshops were mainly Vietnamese, except where technical know-how was needed. Areas of focus included:

- quality training – recognition of key quality attributes for mangoes
- understanding retail requirements – packaging and in-store display
- packhouse training – packaging and HWT
- on-farm training – fertiliser and disease management and sap-burn management.

The workshops and broad linkage activities contributed to better outcomes for farmers, packhouses/collaborators, and processors through:

- better understanding of the market and chain operating practices

- improved understanding of technical supply elements – fruit quality, losses, integrated crop management and integrated pest management
- evidence-based understanding and hands-on training relating to practical improvements in the value chain
- exposure to opportunities gained from minimal and extensive fruit processing.

7.3.4 Research outputs and communications

Research outputs and publications were discussed throughout the project. As mentioned, the pandemic and travel restrictions affected the initial communications plans, and a project website was developed to facilitate communication and the sharing of resources (www.vietnammangonet.org).

The project focus was shared between research studies relating to fresh mango production and trade (supply), and processed mango production. Research output publications and conference papers were encouraged, although this was challenging with the restriction and cancellation of many conferences. At the end of the project, five academic conference papers had been published and seven scientific papers were in progress linked directly to the trialled interventions (see Section 10).

Five key research leads left the project at an early stage and were replaced. Information and knowledge gaps were recognised, and training was begun to support development. In the first 18 months, soft skill courses were delivered in-country. This included presentation preparation, including presenting at workshops; developing checklists; and writing reports, snapshot papers and briefs. Frequent media communications were encouraged and supported to showcase the project's achievements and outputs.

7.3.5 Capacity building

In the last year of the project, workshops designed in a train-the-trainer format for Vietnamese researchers were presented to industry stakeholders (see Figure 7.4 for examples). Leaders from packhouses, cooperatives, farmer groups and local DARD extension officers attended.

Resources were created in both English and Vietnamese in print and electronic formats, and materials were developed in conjunction with SOFRI, SCAP, SIAEP and the lead researchers. The materials include training posters, demonstration booklets and video presentations.

The training and capacity development will contribute to the longer-term development of others in the value chain – farmers, packhouse and cooperative operators and extension officers.

The resources created as outcomes of this project so far have:

- increased the capability within Vietnamese institutions to undertake scientific research
- improved collaboration between stakeholders such as commercial chain partners (packhouse, cooperatives, retailers) and regional and provincial government officers to drive ongoing industry development
- strengthened relationships between Vietnamese research institutes and the commercial operators engaged in domestic mango trade
- built greater understanding and incentive to advance the development of the mango sector in southern Vietnam.

Figure 7.4 Workshop activities, 2018–2022

Source: Project images

7.3.6 Mainstreaming and ongoing development

Annual workshops, midterm and final reviews were delivered by the core research team (SIAEP, SOFRI, SCAP and research leads). The core team also participated in the final project meeting and review, held in September 2022 in HCMC. This meeting walked reviewers through the key interventions (proof of concept/s) to demonstrate areas in the mango value that could readily contribute to practice change in mango quality, and improve mango trade from southern Vietnam.

The researchers from Vietnamese institutions are keen to advance the work completed in this project. For example:

- SCAP, now part of MARD, is initiating a research and training program to identify innovative methods to advance collaborations with farmers and to deliver training and development. Methods used and knowledge gained in this project will be applied in these projects.
- SOFRI is engaged in fruit and vegetable projects with other development programs and will use the knowledge gained from the mango HWT, fertiliser and flowering studies. This will require both a longer-term study of the benefits, and training programs for extension officers to share the information to farm households in mango-producing regions.

A complete summary of key project insights and recommendations for the next steps is presented in Section 9. As advised at the mid-term review, there is no requirement for a Phase 2 proposal, which has been removed from the activity. The project has identified the next steps for research for development as they relate to the project outcomes.

8 Impacts

The work done in this project consisted of initial foundational studies to test small-scale, proof-of-concept interventions on-farm and in the mango supply chain. As a result, and combined with the effects of the COVID-19 pandemic, the impacts that could be achieved in the next five years and into the future are greater than those that could be achieved during the life of the project. The following sections therefore focus on the potential future impacts.

Figure 8.1 shows a thematic map of the project's change pathway, which summarises the main outcomes, outputs, and potential future impact.

8.1 Scientific impacts now and in 5 years

Nutrition program – evidence to inform change in fertiliser use

The project activities analysed current nutritional programs in mango orchards in southern Vietnam. Researchers identified a significant overuse of fertiliser on mango crops. This is a widespread problem in the mango industry in the Mekong River Delta, most likely extends into other horticulture industries in the region.

Farmers are currently encouraged to apply substantial amounts of fertiliser by input service providers, who are supplying advice and advancing credit for fertiliser purchases. However, the studies showed that the amount of fertiliser could be significantly reduced without affecting fruit yield or quality, so there is no need for fertiliser overuse.

The anticipated positive impacts of reducing excessive fertiliser applications include the following:

- Fertilisers contribute 1.5% to greenhouse CO_2 emissions, and N_2O (released from fertilised soils) is 300 times more potent than CO_2 as a greenhouse gas. If fertiliser applications are reduced at a regional level, this could help countries to meet their emission reduction targets.
- Fertilisers contaminate surface and ground water, and increase chloride ions in the soil, exacerbating salination problems. Reducing fertiliser application, as evidenced by this study, will have many positive environmental impacts in southern Vietnam over the coming years.

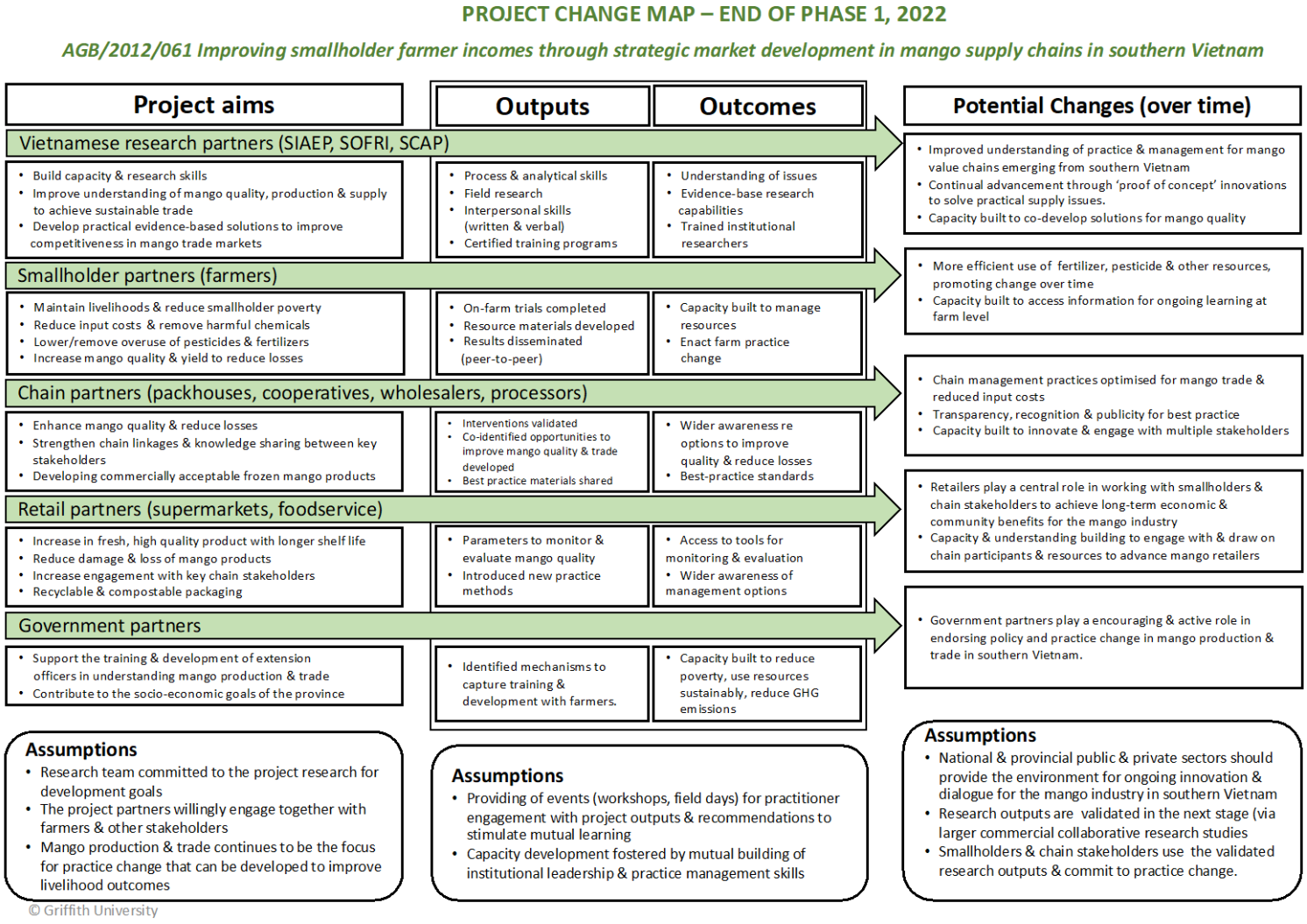

Figure 8.1 Project change map overview, from inception to conclusion and future potential

Source: Project analysis

8.2 Capacity impacts now and in 5 years

Mango production and supply impacts – evidence to inform practice change

The on-farm work with the SOFRI research team has contributed to a practice change that will build capacity in three areas where new knowledge has been gained. These are the excessive use of plant growth regulators and of NPK fertiliser, and the general use of pesticides.

The project innovations likely to generate the most significant capacity impacts to reduce losses and increase productivity and quality outputs directly related to smallholder incomes are described below.

Reliable, out-of-season fruit production

Stakeholders in the mango industry are fully aware greatest returns to smallholders come from out-of-season production. One of the project's capacity-building impacts has been to give farmers and provincial extension officers an understanding that the current dependency on the chemical manipulation of flowering is unreliable, and that practice change is required.

Development of fruit quality parameters related to consumer demand

Current quality parameters are based on fruit size, with large fruit having the highest value. Mango fruit size is strongly related to individual tree crop load. Information has now been shared with farmers to start the conversation about how excessive production can decrease mango quality.

Development of GAP-compliant mango production

The project's stakeholders are now fully aware that the commercial ripening of mangoes is largely dependent on the use of calcium carbide. Stakeholders now have knowledge of links between chemical residue and human genetic damage, changes in fruit chemistry, and the accompanying eating characteristics of the mango.

Farmers are now aware that pest and disease control management is vital to prevent excessive losses during all stages of mango production.

Additionally, the improved GAP, plant nutrition, disease and pest management models informed by this project have great potential to reduce the negative effects of agro-chemical use for farmers, the environment and the consumer while producing affordable, quality fruit. For example:

- The results indicate the impact that fruit bagging has on reducing disease incidence and severity. Combined with chemical treatments such as the antibiotic oxytetracycline hydrochloride, bacterial blackspot can be significantly reduced.
- Similarly with anthracnose, treatment with propiconazole + difenoconazole gave the best results, although all treatments significantly reduced the level of disease, including the reduction of inoculum on flowers.

Farmers, packhouse operators, cooperatives and extension officers are aware that GAP is an administrative tool provided by a certifying agency (private or state-run). However, the benefit of GAP certification to Vietnamese mango supply chain participants from the farm to the consumer is unclear and may emerge over time. For example, farmers have many other channels to sell their fruit without paying for GAP accreditation. For GAP compliance, the farmer therefore needs to be paid more for the additional resources required to become accredited. The project has started this conversation with mango supply stakeholders. They understand it is important, but they will need to see the financial benefit before they start the process in the future.

Farmers do not fully understand the benefits of implementing a GAP system. For high-value crops, such as mango, there is an opportunity to reduce production costs by minimising excessive fertiliser use. Fertiliser recommendation guides need to be communicated to all categories of farmers so they can acquire confidence in using fertiliser and realise the benefits of using recommended nutrients. It is also essential to differentiate the nutrient-use gaps among farm sizes and cropping patterns (main and off-seasons) to control the overuse or underuse of recommended nutrients for profitable crop yield and farm profitability.

Impacts from tested and evaluated supply chain innovations – sharing with wider mango farming communities

The tools that supported innovation sharing were those that support the preferred means of making decisions about the innovation, have a low risk of adoption and are financially beneficial. The preferred means are those that show by example – such as farmer field days, where they are grouped and learn together. The farmers value the personal interactions and hearing the opinions of others and engaging with government extension officers. It is the engagement in such processes that starts the change.

In this project, these tools were the participatory research activities, 'Demonstration Chain' and 'Walking the Chain'. Farmers, packhouse operators and cooperatives actively took part in these activities and provided testimony of the benefits. For example:

- farmers were engaged 'hands on' in trialling mango washing for sap management
- farmers and packhouse operators walked through the HWT process and then applied mangoes through the steps, thus engaging in participatory learning
- farmers and packhouse operators engaged in boxing mangoes ready for shipment to stores
- farmers and packhouse operators were taken to where their mangoes were sold and walked the chain from the end buyer back to their farm.

One example of the benefits gained was gaining retail confidence to purchase from small to medium-sized packhouse operators. The retail agent was pleasantly surprised that such a change in mango product visual quality and presentation could be achieved from this trial. This type of trading arrangement is new for this environment.

For ongoing change and advancement, several seasons implementing the changed processes are needed. This requires a 'champion' to lead this process in an ongoing basis. The champion maybe a combination of retailer and packhouse operator.

Trusted research leads from Australian and Vietnamese institutions have now demonstrated the improvements through a change in processes. The communication channel between farmers, packhouse operators and retailers needs an ongoing development plan through industry engagement to continue the momentum.

In the next five years, continuing investment in key stakeholders (e.g. researchers, extension officers) with the skills and knowledge will build capacity in the industry to recruit farmers and other stakeholders, and influence the ongoing development of the mango trade in southern Vietnam. The 'champions for change' will come from industry leads, such as government extension officers, commune leaders at the farm level and industry development officers (appointed by packhouse operators).

The continuation of the research and development beyond the project has been entrusted to the key institutes in the project. In particular, the Vietnamese research institute, SOFRI, has a strong understanding of agriculture and agribusiness, is fully engaged in resource development and preparation, and has regular communication (e.g. events, workshops) with farmers, packhouse, cooperatives and DARD extension offices in the provinces. Note that there is no formal mango industry organisation in Vietnam operating as a peak body for disseminating resources.

8.3 Community impacts now and in 5 years

8.3.1 Economic impacts

The focus of the project was to identify current impediments in mango supply in the domestic market of southern Vietnam. Realistically, not all the activities undertaken will have a long-term or direct economic impact. However, one or two could have significant impacts on industry practice change.

The studies on fertiliser showed that it can be reduced without affecting fruit yield. Combined with improvements in mango shelf life and quality, this will reduce losses and improve the profitability of smallholder farm enterprises. These studies therefore identified an issue that could have economic impacts at the farm level and the national level (balance of trade), as Vietnam currently imports a vast amount of fertiliser.

The 'Demonstration Chain' and 'Walking the Chain' final activities validate the use of demonstration as a mode to deliver economic impact. Both activities overpoweringly demonstrated the impact of engaging farmers in the process of change to improve mango quality and trade, starting at the farm level. The farmers' active participation in 'walking' the path that their mango follows when traded was unique in Vietnam. In Australia, this type of activity is undertaken annually – and is proven to act as a conduit for behaviour/practice change and forming networks with enduring legacies.

Often the greatest economic impacts will happen over time, and/or from market forces, driving change in trade practices. Several packhouses have now adopted sap management practices. Processors have enquired about the freezing of supply, and some are actively seeking freezer space to do this. The supermarkets have indicated they want more demonstration fruit (i.e., those that have undergone sap treatment and HWT, and in new packaging, as shown in the intervention study). The fertiliser analysis trial results provide an excellent platform for refining trial results and engaging extension services and policymakers to look at the issue of fertiliser overuse.

The HWT activity (conducted in Australia) will be significant for the Australian mango export industry and the basis to start bilateral negotiations on import protocols. It therefore delivers a significant contribution to the project. The results demonstrated and confirmed a HWT process that will give any mid-sized mango packhouse in Vietnam the opportunity to export their fruit. The vast majority of Vietnamese packhouses do not have logistical access or financial capacity to use the services of vapour heat treatment or irradiation plants.

8.3.2 Social impacts

The project did not seek in the first phase to have any major transformative social impacts in the nominated provinces of Dong Thap and Tien Giang. Mango is widely grown by rural smallholder households in southern Vietnam. The industry and communities in this region are directed by government priorities for mango production and trade. The project's analysis revealed the importance of mango as a priority crop. The farmers are fully committed to growing mangoes and believe it can contribute to their livelihoods and are therefore keen to improve their orchards instead of farming other types of produce.

8.3.3 Environmental impacts

In the next five years and beyond, reductions in fertiliser and other agrochemical usage as informed by the project could have significant positive environmental impact. Changes in farming practices could benefit the environment by reducing soil and water contamination and reducing greenhouse gas emissions to the atmosphere.

Advancing GAP implementation and achieving compliance will also make a significant contribution to environmental impacts in the region. Change in mango farming practices is

necessary for this to occur. This is a priority for the Vietnamese government and is evidenced by formal directions at the provincial level.

Environmental impact mitigation should be considered in future work.

8.4 Communication and dissemination activities

The project brought together a multi-country, cross-disciplinary team with diverse, collective expertise in agribusiness, economics, agriculture, and gender research.

After completing each year's undertakings, each research group presented written reports detailing the collective research outputs of each activity. Examples of project communication and dissemination activities that will achieve impact in the future include the following.

Resource materials

The research team prepared resource materials as training aids in a train-the-trainer format, and in English and Vietnamese. These were distributed at seminars and sessions given by researchers to extension officers and lead farmers at provincial information sessions (see list below). The materials provide information that will help farmers run their farms more efficiently and productively in the future.

Workshops

Lead activity researchers presented the results of their activities via in-country workshops and online presentations (see https://vietnammangonet.org/publications-and-training). Training resources in English and Vietnamese were prepared from these results. The three Vietnamese institutions have an ongoing role – especially SOFRI, located in the southern provinces – to deliver training and development for future impact through the provincial DARD offices.

Publications

Some presentations and submissions to industry and scientific conferences and publications for wider distribution with institutions engaged in mango research for development have been completed, while others are in progress (see Section 10). These publications validate the outcomes of the intervention trials. Work completed in the use of sap management and HWT can be applied to not only Vietnamese mango production, but also to other mango-producing countries in the region, such as Cambodia, the Philippines and Indonesia.

Extension and training resources developed in the project

Video resources

2022. *Understanding Mango Quality*, Walking the Chain demonstration video.

2022. *Mango Retailing,* Walking the Chain demonstration video.

2022. *Sap Management*, Walking the Chain demonstration video.

2022. *Hot Water Treatment*, Walking the Chain demonstration video.

2022. *Packaging for Retail,* Walking the Chain demonstration video.

2022. *Fertiliser Management*, Walking the Chain demonstration video.

2022. *Alternatives to PBZ*, Walking the Chain demonstration video.

Training posters

2022. Demonstration 1: Supply Requirements & Display, Project Resource.

2022. Demonstration 2: Grading & Packing, Project Resource.

2022. Demonstration 3: Hot Water Treatment, Project Resource.

2022. Demonstration 4: Sap Management, Project Resource.

2022. Demonstration 5: Flowering – Alternative to PBZ, Project Resource.

2022. Demonstration 6: Fertiliser Management, Project Resource.

2022. Demonstration 7: Disease Management, Project Resource.

Demonstration booklet

2022. Changing Practices to Advance Mango Trade, A5 demonstration booklet.

Media communications resulting from the project

Stone, S. 2022. Griffith walks the supply chain with mango farmers to improve trade outcomes. Griffith News 25 October.
https://news.griffith.edu.au/2022/10/25/griffith-walks-the-supply-chain-with-mango-farmers-to-improve-trade-outcomes/

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https://news.griffith.edu.au/2020/10/21/online-education-enables-research-aid-project-to-continue-through-worst-of-covid-19/

2019. Getting a sweet return on mangoes. Griffith News 8 February.
https://news.griffith.edu.au/2019/02/08/getting-a-sweet-return-on-mangoes/

2019. Getting a sweet return on mangoes. Australian Centre for International Agricultural Research 8 February.
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2018. Australian project helps improve mango farmers' income. Vietnam+ 20 September.
https://en.vietnamplus.vn/australian-project-helps-improve-mango-famers-income/138684.vnp

9 Conclusion and recommendations

This project identified and examined opportunities to increase competitiveness in fresh and processed mango value chains in southern Vietnam. Proof-of-concept interventions were evaluated to overcome selected production and trade barriers. Activities were principally led by in-country researchers with strong connections to farmers, packhouse operators and retailers, which improved capacity, industry stakeholder linkages and knowledge sharing.

9.1 Conclusion

The main insights are summarised below. Refer also to Figure 8.1 for a thematic map of the project's main outcomes, outputs, and potential future impact.

Insight 1 Disease and pest management

Pre- and post-harvest diseases limit domestic and export market potential. The project validated mango bagging as a practice to manage fruit fly, suppress disease and reduce chemical use. More understanding is needed of control methods to apply pre-bagging, combined with a postharvest disease-management program.

Insight 2 Fertiliser management – Cat Chu and Cat Hoa Loc mangoes

Incorrect application of fertiliser is common, with overuse the leading contributor to poor crop nutrition. The overuse is far more than can be attributed to crop removal, growth and loss through runoff and volatilisation and leaching. This can impact fruit quality and disease susceptibility and contribute to environmental pollution.

Insight 3 Expanding seasonal flowering in Cat Hoa Loc mangoes

UCZ and ProCal were studied as alternatives to PBZ to produce off-season mangoes. Yields were low, but results were inconclusive due to the short time between inhibitor application and chemical floral induction. However, the work indicated treatments that may reduce chemical inputs for comparable, and potentially increased, out-of-season yields.

Insight 4 Hong Kong and export opportunities

Australia and Vietnam currently export a small percentage of mangoes due to high domestic demand. Vietnam has limited trading experience in HK, but a seasonal shortage of mangoes presents a future opportunity for trade with HK. Mango consumption is growing across the EU, with difficulties in sourcing fruit. Australian and Vietnamese mangoes can meet export requirements, consumer and market expectations in the EU.

Insight 5 Efficacy of a demonstration chain

Improvements in costs–benefits arising from sap treatment, HWT and boxing mangoes were seen in a commercial demonstration chain. Chain stakeholders are committed to continue the practice. Consumers in HCMC are willing to pay almost double for high-quality, treated Cat Hoa Loc mangoes and up to 10 times the price of other untreated varieties. Connecting producers and other stakeholders with markets/retailers will grow understanding of quality requirements, compliance, production and supply constraints.

Insight 6 Processed mangoes – the freezing opportunity

Small-scale production units make the instability in supply of mangoes challenging for processors. Limited access to technology and infrastructure has impeded the growth of more sophisticated processed fruit products. Data from the preliminary trials supports the adoption of freezing by current and future manufacturers. There is a need to develop and improve commercial practices for frozen processed mango, including packaging formats.

9.2 Recommendations

R1 Develop a model mango disease-management system

Incorporate activity outputs into a model mango disease-management system to assist smallholder farmers in Vietnam. This would combine reductions in orchard inoculum and postharvest disease control with cool chain management for a holistic approach.

R2 Develop a mango orchard nutrition-research program

Assess and quantify the extent of fertiliser overuse, and nutrient loss in waterways and ground water, in southern Vietnam mango farming communities. As the issue of mango orchard nutrition is widespread across many ACIAR partner countries, conduct comparable sampling in Cambodia, the Philippines and Indonesia. Implement long-term nutritional studies to refine application techniques, timing and quantities, and measure quality improvements. A training agenda for developing nutritional plans could form the basis of an accredited training program for farmers, service providers, extension officers and researchers. A program highlighting policy areas that would raise industry awareness of fertiliser overuse, alternative products and registrations could drive practice change.

R3 Evaluate the commercial viability of fungicide and hot water treatment in short, medium and long-distance markets

Examine fungicidal treatment of harvested fruit to suppress disease and increase quality to command price premiums in a competitive market environment. Chitosan has yet to be fully validated as a useful fungicide for short to medium-distance markets, such as Hanoi and China. Further commercial testing of HWT incorporating chitosan is needed for these markets.

R4 Strengthen public–private partnerships in support of R&D for mango trade

Develop public–private partnerships with the key stakeholders (farmer groups, packhouse operators, cooperatives, and local DARD officers) operating as value-chain ‘champions’ to continue the immediate past impact of the demonstration chain activity. R&D activities could include developing this model further, with a focus on reducing fertiliser and quality management; extending and upscaling the model into commercial operations across southern Vietnam; creating a best-management practice guide; and setting up accreditation programs so farmers can access modern retail contexts in domestic and export markets.

R5 Examine how trade partnerships in the Hong Kong and/or European Union markets of could advance exports of Australian and Vietnamese mangoes

Prioritise a study of mango exports for new Australian and selected Vietnamese varieties in HK and the EU. Develop an export plan to assist and target the development of new export markets. Undertake a buyer acceptance study in key export markets for Australian and Vietnamese varieties to aid in understanding specific buyer requirements for market segments such as premium retail, e-commerce, food services and ready-to-eat cut fruit.

R6 Engage in policy dialogues on fruit processing business opportunities for the tropical fruit sector in Vietnam

Take the first-stage results from the preliminary freezing trial to the next level. Facilitate a series of dialogues to establish the validity of, and seek endorsement for, the Recommended Procedure for Processing and the Code of Practice documents for frozen fruit as the accepted method for enterprises and DARDs in the southern Vietnamese processing sector. Identify opportunities to develop government-endorsed, regional training and accreditation across provinces for freezing procedures for regional fruit and vegetable processing.

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