Analysis of mango production practices and R&D needs

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QLD Department of Primary Industries and Fisheries

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FINAL REPORT

MG04004. Review of Mango Production Practises

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1. Media Summary

A key objective within the Australian Mango Industry Association Strategic plan 2004 -2009 was to achieve improving marketable yield, plantation profitability and environmental sustainability. One of the three key strategies identified for achieving this objective was the development of best practice production systems to minimise costs, maximise yields and optimise fruit quality.

This report analyses current production practices across all Australian production regions, initially to establish a benchmark on, current production management practices, attitudinal responses to various management practices and some statistical data on tree planting, variety, yield and labour costs. Secondly, but more importantly, to analyse these practices to determine priority Research, Development and & Extension activities likely to deliver greatest return (grower benefit) on industry investment.

Analysis of the key issues and focusing questions developed from regional "extraction workshops" together with the confidence and attitudinal responses from benchmarking surveys, identified six key long term sub-strategies to address the over all intent of Strategy 3. These are:

Key Sub-Strategies

1. High yielding orchards, designed to have blocks that can be harvested sequentially with a maximum of 2 passes, supplying quality fruit to targeted markets for a maximum period of time.
2. Pest management systems that use Integrated Pest Management principles to provide quality fruit to targeted markets, without the use of post harvest treatments.
3. In-field disease management strategies that ensure that fruit is robust enough to have 45 days shelf life and that reduces or removes reliance on post harvest treatment.
4. Production and harvesting systems that minimise labour requirements and costs of production and handling without negative impact on fruit quality
5. Fruit maturity standard and harvest prediction indices for each variety
6. Packing sheds and handling systems that maximise product throughput, improve fruit quality and systems that allow for product traceability.

A major emphasis for AMIA over the next five years needs to be directed towards technology transfer. The survey and workshops clearly indicate that there are three tiers of grower competency across the industry.

The three tiers are:

1. Growers with advanced production and management skills, drawing on a wide range of knowledge sources, utilising consultants where necessary and willing to evaluate new technology. These may be individual growers or corporate enterprises. Active information seekers.
2. Growers with average production skills but below par management capacity. They are generally slower in picking up new technology and rely more on the local reseller or neighbour for the information. Generally come to field days but not training workshop. Do not actively seek new information

3. Growers with well below the average production skills and limited management capacity. Relies heavily on sales representatives (of all qualities). Does not attend information days. Resistant to new ideas.

The challenge for this plan is to develop technology transfer systems that provide the opportunity for all growers to benefit from the AMIA investment. A range of programs that address one or more of the six sub-strategies has been recommended. These are;

1. Technology Transfer. A web based data base that can house all past research and extension material, and also have the capacity to be updated with new data as it becomes available.
2. Unlocking Research. This project uses grower based panels in regional areas and on-farm trials to improve adoption and understanding of key orchard management concepts.
3. Disease management. This specific focuses on adopting outcomes from considerable ACIAR project activity into the Australian production system, to address the many serious disease management issues, but into a total crop management system.
4. Insect management. This also focuses on adopting outcomes from considerable ACIAR project activity into the Australian production systems, but with a focus on market access issues within the framework of a total crop management system.
5. Fruit maturity index. Development of a quantitative measure of fruit maturity at harvest that relates to the consumers' expectation of fruit flavour and shelf life.
6. Crop Forecasting. Validation of the data set across all of the industry.
7. Analysis of Harvest aid systems focusing on labour efficiencies and fruit quality issues.
8. Independent review of the packing shed including to "Time-in-motion" studies identify efficiency areas and WHS issues.

2. Introduction

The Australian Mango Industry Association (AMIA) strategic plan 2004-2009, established five basic objectives. These are summarised as:

1. Deliver to the consumer and market, preference in term of eating quality and consumer satisfaction.
2. Building domestic market consumption through marketing and promotion.
3. Improving marketable yield, plantation profitability and environmental sustainability.
4. Developing and maintaining excellent communication throughout all sectors of the industry.
5. Support the development of new export and processing markets and maintain and further develop existing markets.

Objective 3, improving marketable yield, plantation profitability and environmental sustainability, has the following high level performance indicators aligned to it;

a. Have in place a comprehensive eating quality improvement program, which is demonstrably delivering higher average levels of consumer satisfaction, as measured by market research.
b. Increased industry average marketable yield by 5% up from 40-45%.
c. Have demonstrated the ability to reduce plantation costs by 5% at a trial level through improved genetic selection and/or plantation management practice.

The rationale behind objective 3 was that the profitability of the mango industry in Australia is being adversely affected by:

a. Low marketable yield due to the heavy reliance on the delicate nature of the Kensington Pride variety.
b. Relative high plantation costs due to the labour intensity of the category and the high chemical costs.
c. The tendency of biennial bearing.

Three strategies within objective 3 were identified to progressively improve plantation profitability.

1. Varietal improvement
2. Develop best practice production systems to minimise costs, maximise yields and optimise fruit quality.
3. Facilitate effective incursion and biosecurity management.

It is strategy 2 that is the major focus of this report. This report provides further clarification of the priorities within this strategy. As the strategy encompasses the full range of grower practices this prioritisation was a necessary step to ensure that AMIA was well informed to make the most effective investment decisions. The information necessary to support the initial and ongoing decision making for investment for this strategy has been developed by;

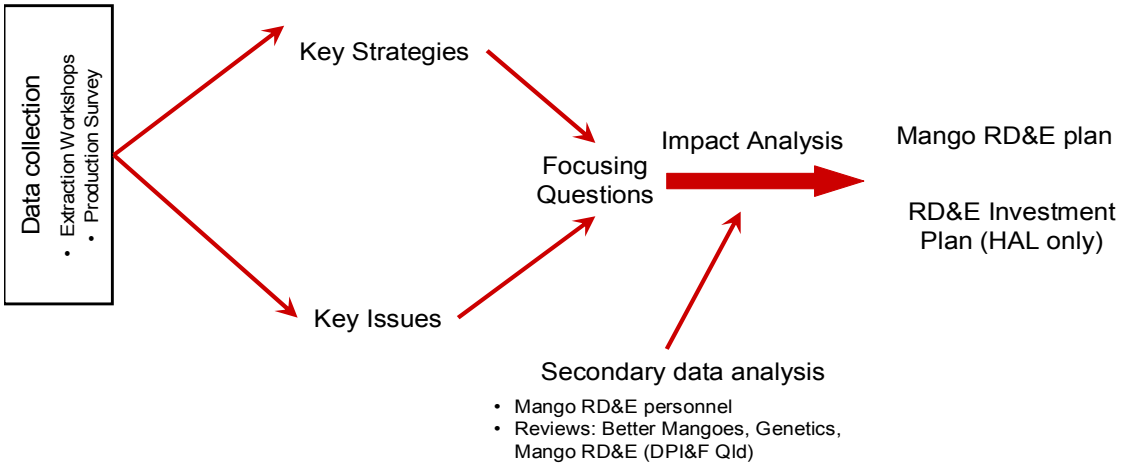
a. Analysis of current industry production practices to establish benchmarks for future references,

b. Monitoring advances in production systems over the life of the strategic plan to measure benefits from investment strategies,
c. Analysis benchmarks of current practice to determine priority R&D strategies likely to deliver greatest grower benefits and
d. Improving industry knowledge and skills in production systems through action learning programs.

This review was lead by DPI&F in collaboration with NTBRID, AGWA and CSIRO and in consultation with HAL and AMIA.

The focus of this project is firstly to analyse current production practices and establish benchmarks for future reference. Secondly, but more importantly, was to analyse these current practices to determine priority RD&E activities likely to deliver greatest return (grower benefit) on RD&E investment through minimising costs, maximising yield and optimising quality whilst supporting environmental sustainability. The data collection process developed by the project team consisted of two approaches to maximise the quality of data. Initially a benchmarking survey then regionally based workshops to focus growers on the critical RD&E issues. Diagram 1 summarises the overall process that the team followed, to develop the Investment Plan.

Diagram 1



3. Benchmarking Survey

A. Introduction

This survey concentrated on collecting quantitative and qualitative data on current production management practices, attitudinal responses to various management practices and some statistical data on tree planting, variety, yield and labour costs.

The main objectives of this survey were:

- Determine current management practise amongst the mango industry
- Understand how decisions relating to orchard management, harvesting and postharvest handling are made
- Provide benchmarks of knowledge and attitudes to orchard management, harvesting and postharvest handling as a reference point for future evaluation
- To help guide future research, development and extension in mangoes

B. Method

This survey was conducted from March to September, 2005 targeting mango growers in all mango growing districts throughout Australia. The survey was based around a similar survey of mango growers relating to mango pest and disease management conducted during the Mango Plant Protection project: Phase 1 (HAL FR02050).

The survey asked a range of questions covering most aspects of orchard management, harvesting, packing and financial management. Different types of questions were used throughout the survey to gather information on actual practise as well as attitudes, perceptions and opinions relating to their own orchard and packing shed.

At the end of each management section, respondents were asked about how confident they felt in making decisions relating to that management practise. A copy of the survey is attached in Appendix I.

To shorten the survey, we attempted to collect copies of individual grower's spray and fertiliser records. Each grower's records were to be kept confidential. Growers attending the extraction workshops were asked to bring their farm diaries (or copies of these) to the meeting so this information could be collected. Where the survey was mailed out, growers were asked to return the survey with a copy of their spray and fertiliser records.

The questionnaire was initially tested as a person-to-person interview with several growers in the Burdekin and Mareeba mango growing districts. Based on the feedback during these initial interviews, changes to the questionnaire were made to remove ambiguity and simplify some questions.

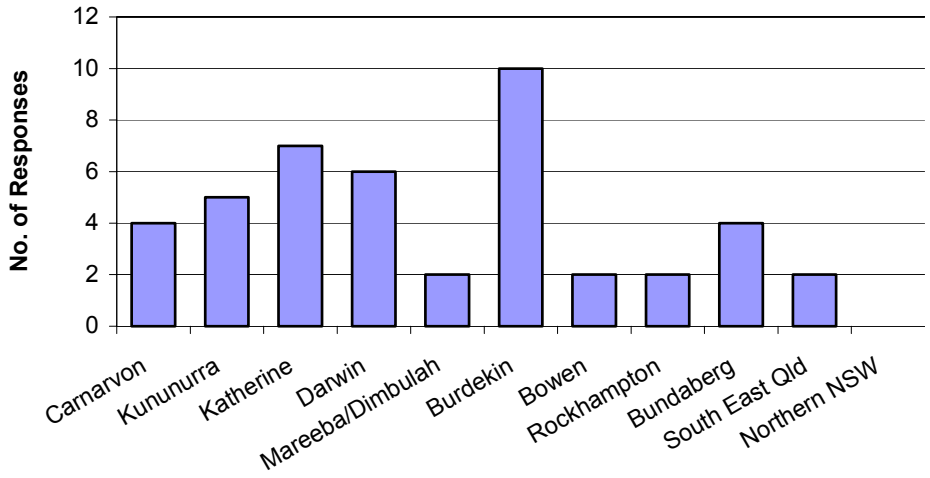
The questionnaires were mailed out to mango growers for them complete. This allowed time for the growers to think about the questions before answering, find the information in their records to answer specific questions and also limited the influence the project team had on the answers given as the data was collected.

Growers who were attending the Extraction workshops were asked to bring the surveys with them. The remaining surveys were either collected during follow-up interviews or the growers were asked to post them back when completed.

C. Results & Discussion

The response rate of 44% for the survey was good considering its complexity. Where possible, the project team tried to collect surveys either during the Extraction workshops or personal visits being conducted as part of the Better Mangoes review project.

Figure 1. Distribution of the responses to the survey



The lowest response was from Mareeba Dimbulah area. Of the 12 surveys distributed only 2 surveys have been returned despite continually follow-up. Four growers have agreed to fill the survey out following the 2005/06 mango season and these results will be incorporated when the survey forms are been returned.

There was a poor response to the extraction workshop held in Mareeba in March 2005 with only 2 growers attending of the 16 invited. Both of these growers failed to return the survey form.

While this may reduce the validity and applicability of some of the results, the cross section of mango growers who did fill out and return the survey from others areas has provided a good snapshot of industry.

The idea of collecting grower's spray and fertiliser records was unsuccessful. Mango growers appear to be happier to answer questions about their spray and fertiliser records than provide actual copies of them.

Orchard details

The surveys collected represent approximately 300,000 mango trees from 214 blocks on 45 farms. This cross section of industry was made up of a number of varieties including 60% Kensington Pride, 14.4% R2E2, 12.7% Honey Gold, 7.7% Calypso and 4.9% other varieties including Keitt, Nam doc mai, Palmer and Haden.

Table 1. Orchard characteristics for the main mango varieties planted in Australia

	Tree age (yrs)	Average tree density (trees/ha)	Average tree spacing	
			Row (m)	Tree (m)
Kensington Pride	12-13	185	9	6
R2E2	9	222	8	5
Keitt	11-12	318	8	4
Calypso	3	365	8	4
Honey Gold	3	357	8	4

The oldest mango trees included in the survey were Kensington Pride (35 years old). For R2E2 it was 21 years old while for Keitt it was 17 years old. However, the oldest Calypso and Honey Gold orchards within the survey were 6 to 7 years old. It will be several more years before reliable commercial data on yield for these varieties can be collected.

Table 2. Yield per hectare for different varieties

	Yield (kg/ha)	
	Max	Ave
Kensington Pride	31,746	10,036
R2E2	60,286	12,549
Keitt	37,054	16,392
Calypso	17,500	7,460
Honey Gold	8,438	3,421

Insufficient data was collected from the survey to compare canopy size across regions or general phenology of the varieties grown by respondents. Other basic data recorded was:

- Common and KP are the main rootstocks used for grafted trees
- Mangoes are being grown on a wide range of soil types from light sandy loams to red clay loams to heavy black clay soils
- Only a small number of orchard used windbreaks which were usually made up of natives including Eucalyptus and Casuarina species

General

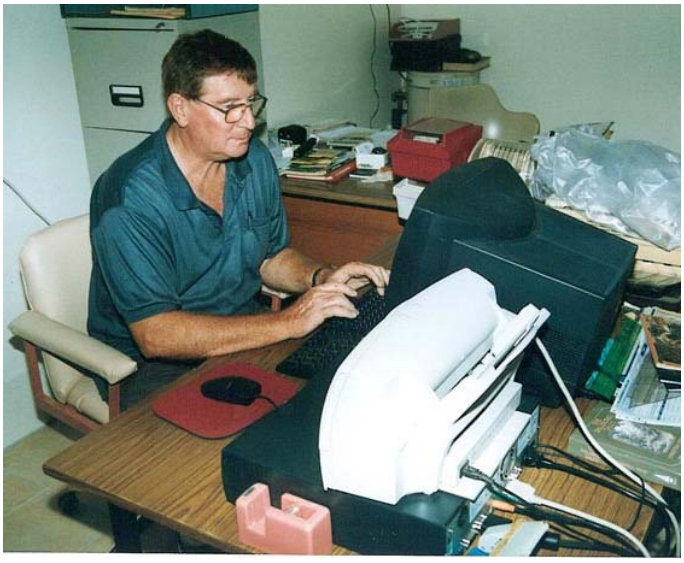
Only 43% of respondents currently record their farm management practises on their computer while only 9% currently use a computer-based farm diary system. However, 80% said they would use a computer based farm diary system if a suitable program was available.

The main requirements from this system would be to store and print chemical and fertiliser records and other documents required by food safety, quality and quarantine accreditation systems such as FreshCare and Interstate Certification Assurance.

A number of questions relating to computers and the Internet remain unanswered from the survey. Recent agricultural and horticultural industry surveys have suggested widespread use of computers.

However, little is known about how computers and the Internet are used by industry, particularly mango growers. Are they used mainly for communication with supply chain partners (i.e. email)? How many mango growers use the Internet to find information to questions they want answered? What are the main topics they use the Internet to search for?

Over 80% of respondents said they would use a computer based farm diary recording system if it was available. However, little is know about the value and use of the Internet to Australia mango growers



The answers to these questions are important considering the current strong focus on using email and the Internet to deliver electronic information by bodies such as AMIA, Government service providers and many other information providers.

Growers were also asked if they would change their farming systems to meet certain export protocols. This question was particularly relevant with the recent approval of quarantine requirements for export to China of Australian mangoes.

Ninety eight percent of respondents said they would change their system to meet quarantine requirements for specific export markets. However, a number of growers clarified their response by saying the returns would need to be viable to warrant the costs.

Information sources

A list of possible information sources was presented to growers and they were asked to rate these sources as

- *'Important and often used'*
- *'Sometimes used' or*
- *'Never used or not important'*

The results were grouped separating people (Figure 2) people or products (Figure 3) as the preferred source of information.

Local Departmental officers rated highest in importance amongst the various people mango growers used as an information source. This result was possibly influenced by the large numbers of surveys which had to be collected by this group. Other growers and People in Industry associations were also rated highly.

Chemical resellers, Chemical Companies, Market agents were sometimes used as an information source. However, the use of Pest scouts & consultants was surprisingly low compared to the other information sources.

Figure 2. The importance of people as sources of information for mango growers

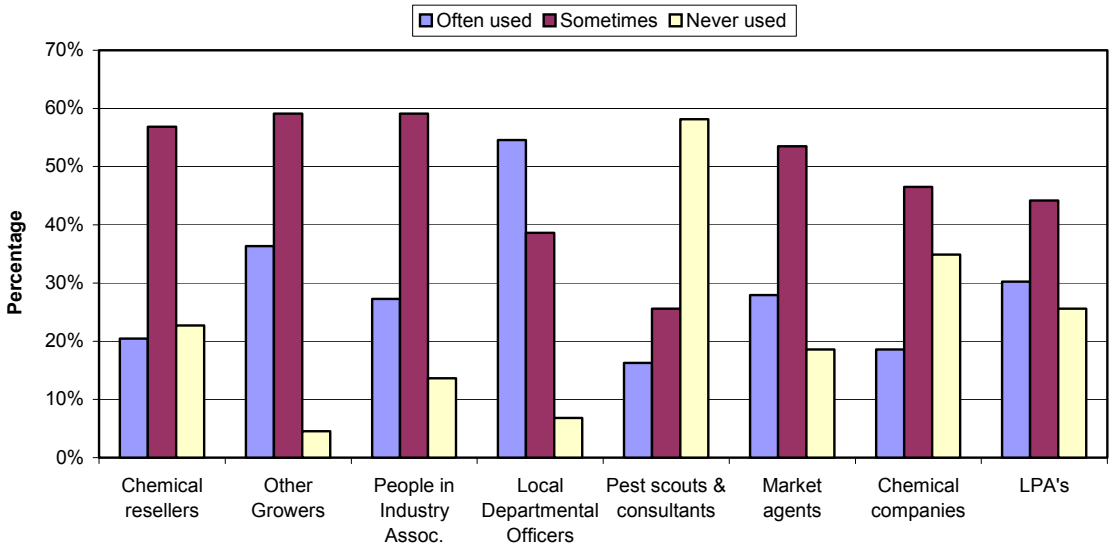
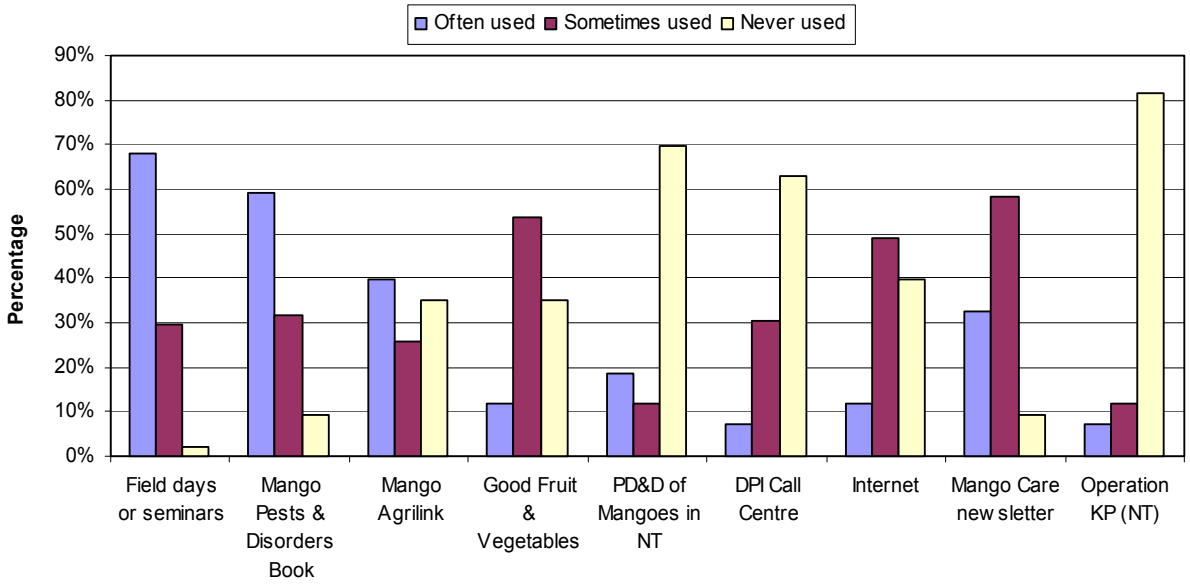


Figure 3. The importance of products as information sources for mango growers



Field days & Seminars, the Mango pests & Disorders book (DPI&F) and the Mango Care newsletter were the most valued products according to respondents who drew on these products often and sometimes. Only a small percentage never used them as a source of information. The Mango Agrilink, Good Fruit & Vegetables magazine and the Internet also rated as an occasional information sources but a higher percentage never used these resources.

The DPI&F Call Centre rated moderately for Queensland and NT growers but very poorly for WA respondents.

The use of the Internet as an information source was higher as compared to an earlier information study conducted with Queensland mango growers in 2003. Western Australian respondents rated the Internet higher than other states.

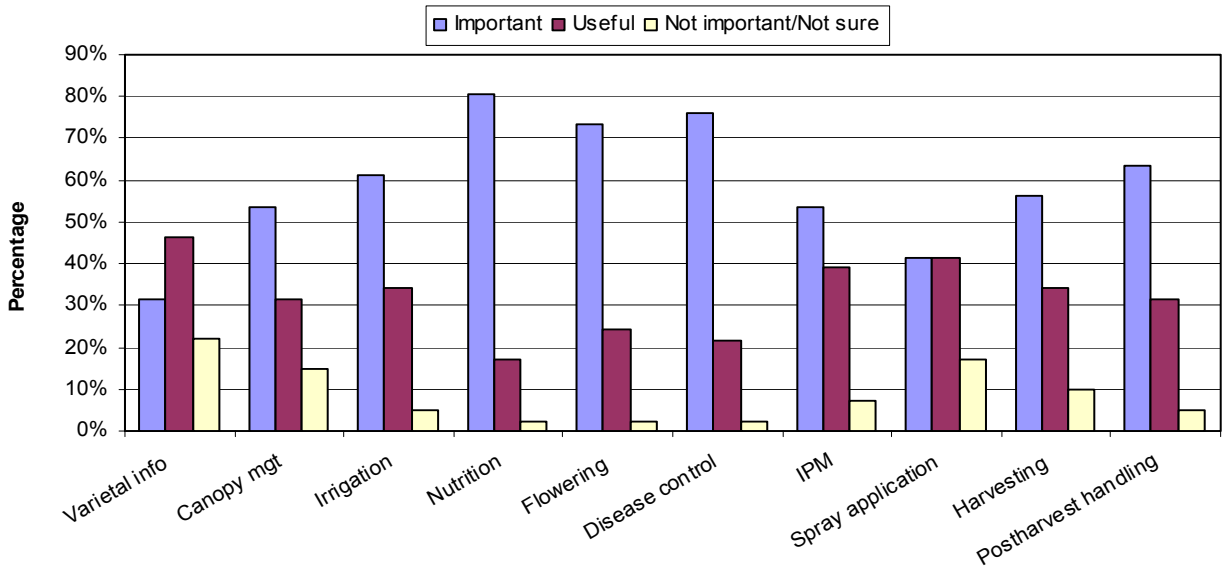
The book "Pest, Diseases & Disorders of Mangoes in the Northern Territory" rated highly amongst NT respondents (85% used it Often or Sometimes for information) but rated poorly with growers from Queensland and WA. "Operation KP" had a similar rating. This is possibly indicating that regionally based information is used locally but growers in other areas are not aware of these resources.

Information needed

Mango growers were asked to identify areas in which more information would help them to make better decisions in growing, harvesting and packing mangoes. They were asked to rate these areas 'Important', 'Useful' or 'Not sure or Unimportant'. The responses have been divided into orchard management and other information topics for this analysis.

With the exception of Spray application, these results are similar to those observed in 1997 from the "Improved Technology Transfer within the Mango Industry" project (Holmes, R.J. et.al., HAL FR97008) and would appear to remain important areas to mango growers in 2005.

Figure 4. Information needed to help make better orchard management decisions



Overall, growers indicated that more information on all the orchard management topics listed in the survey would be useful for better decisions. More information on nutrition was the most important across all growing regions. Information on Flowering and Disease control was important for respondents in Queensland and NT but had significantly lower ratings amongst WA respondents.

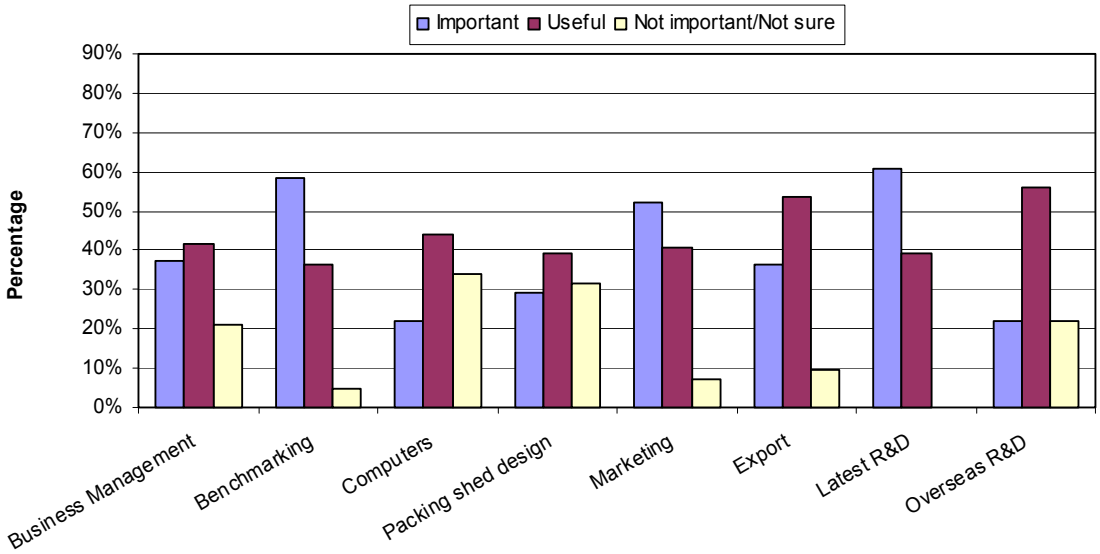
Information on Canopy management, Irrigation, IPM, Harvesting and Postharvest handling were all ranked highly. Nutrition, Canopy management and Irrigation are emerging issues for future R&D and industry effort.

Information relating to spray application wasn't rated too highly with most respondents split between important (40%) and useful (42%). This could be due the number of spray application workshops that have been run in many mango growing areas in recent years and highlights the earlier reported preference of growers to field days and the significant impact of

these types of technology transfer in changing attitudes of growers. However it was significantly low amongst WA respondents, with only 11% rating it as important. This reflects more the low incidence of pests and diseases in WA.

Information on varieties had the least importance of all management topics across all growing regions. The NT was the only area where some respondents rated nutrition, flowering and disease control information as not useful or not important.

Figure 5. Information needed to help make better orchard management decisions



Benchmarking, the Latest R&D and Marketing were the most important 'Other' areas of information that growers considered would assist them in making better decisions. Generic access to the latest research results rated highly with 61% of respondents rating it important. It was also the only topic which all respondents rated as either important or useful. Clearly indicating that they are aware that research has been conducted, but they are having difficulty in obtaining the outcomes of the work

While the 'Benchmarking' response was positive, it shows that there are still many mango farms that consider themselves individual units rather than part of a larger industry and are not interested in comparing themselves with others.

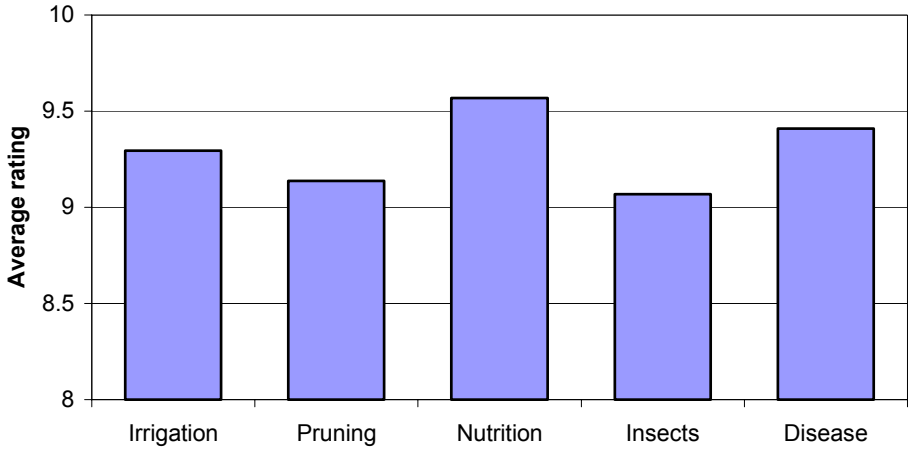
Some regionally difference showed again. NT growers rated Business information much higher than other states. Western Australian respondents rated the Latest R&D much higher but rated information relating to export low. This is possibly due to the export programs currently being run by the Department of Agriculture in WA. They also rated Business management and Benchmarking information lower in importance then either Queensland or NT growers.

'Computers', 'Packing shed design' and 'Overseas R&D' were the least important information topics across all growing regions. The low importance computer information was surprising considering the interest in the Internet as an information source and high percentage of respondents who said they would use a computer based farm diary recording systems if one was available (80% or respondents).

Importance of management practises

Mango growers were asked to rate the importance of certain orchard management practises in relation to yield and fruit quality on a scale of 1 to 10 with 1 being "Not important" and 10 being "Very important".

Figure 6. Importance of orchard management practises in relation to yield and fruit quality



All 5 management practises listed, irrigation, pruning, nutrition, insects and disease were rated "Very important" with averages ranging between 9 and 9.6. Nutrition was ranked the most important with 91% of responses rating it 9 or 10 in importance, followed by Disease.

Costs & returns

Throughout the survey, growers were asked to provide information on their costs of production and returns to develop benchmarks and identify the impact of the various management practises on costs and profitability.

Insufficient data was collected to provide a clear reflection of these costs across the various growing regions. Costs of production for 1 hectare of mangoes varied from $500 to $10,900, with average figures between $2100 and $2700 per hectare. Pruning followed by pest and disease control and fertiliser were that main costs.

Returns varied dramatically possibly due to their variation during any mango season as supply and demand vary.

Canopy management

All of the growers surveyed were using a combination of mechanical and hand pruning in their orchard. "Topping" or lowering the height of the trees was exclusively done using mechanical pruning by the growers surveyed. It was used to prune the sides of trees and "lift the skirts" by a considerable number of the respondents. Mechanical pruning was done immediately after harvest in all growing regions.

Hand pruning was used to prune the inside of trees and open up the canopy for light penetration. Some growers used hand pruning in the place of mechanical pruning in shaping their trees. Most hand pruning was done during the month after harvest. Several growers delayed their hand pruning until May or June when the trees had entered their dormancy phase.

While there were some commonalities between growers in the method of pruning, every grower had a different way of pruning their trees. Variations covered the importance of timing particularly for hand pruning, individual trees as opposed to hedge-rows, how often to prune and its purpose.

Most 'pruning's' are slashed or mulched in the inter-row, some are swept back under the trees while others are just left in the inter-row. Only one respondent removed pruning's completely from the orchard.

Approximately half of the growers surveyed were applying a growth regulator to some or all of their orchard. The timing varied from annual application to once every 3 years and was always applied by hand as a collar drench.

Fifty nine percent of growers have seen their mechanical pruning contractor clean his equipment either before coming onto their property or on departure. Most commonly a pressure cleaner with a detergent solution to remove sap and other rubbish was used. In a small number of cases they used bleach or a similar chlorine solution. Only one grower said he cleaned the machine himself.

Irrigation

Micro-sprinklers were the most common irrigation method amongst the mango orchards surveyed. Six growers have blocks under trickle irrigation but only 2 of these had their whole orchard under trickle. Only one grower was using flood irrigation to irrigate some blocks on his farm and was using trickle to irrigate the others.

Growers were asked a series of questions relating costs and water usage. The responses to these questions varied widely in particularly questions costs making it hard to extrapolate from them.

The amount of water applied varied from 0.8 to 12.5 mega litres per hectare. Five to six mega litres per hectare per year was the average amount of water being applied to mango orchards.

The amount of water applied during various crop growth stages varied widely amongst growers and between regions. Most water was applied during the fruit development stage followed by fruit set and flowering (Table 3). Most growers (75%) irrigated their orchards through the harvest period while 25% didn't apply any water during the first flush.

Table 3. Average percentage of water applied at various growth stages of the crop

	Flowering	Fruit set	Fruit Development	Harvest	1st flush
Average	20%	22%	38%	10%	10

The majority of growers surveyed were sourcing their water from an irrigation scheme (33%) followed by either regulated (28%) or non regulated bores (18%). In several cases, growers were using 2 sources for their water.

The price paid for water varied depending on location with some growers paying as much as $1000 per mega litre. Those located within irrigation schemes averaged between $30 and $60 per mega litre. Thirty eight percent of respondents paid nothing for their water.

The fixed costs of applying water averaged $260 per hectare. The costs to pump water for 1 hectare of mangoes ranged between $230 and $350 per year.

Table 4. Sources of water used by mango growers to supply water to their orchard

Source		%
Regulated	Supplemented stream	9
	Bore	28
	On farm dam	5
	Irrigation scheme	33
Non Regulated	Stream or river	2
	Bore	18
	On farm dam	5

Growers were asked how they knew when to irrigate their orchard. Most growers used a range of tools to decide when to water their trees. Moisture monitoring equipment (51%) was the most popular tool followed by pan evaporation rates combined with crop factors, experience and visual observation of the soil and trees. Growth stage (flowering, fruit set etc.) was another tool used.

Over three quarters of growers have used some form of moisture monitoring equipment in their orchard. Of these, close to 80% were still using the equipment to schedule irrigation. Tensiometers were the most popular (42%) followed by capacitance probes such as Enviroscan or Agrilink (33%). Gofer's accounted for only 15% of moisture monitoring equipment.

The main reason growers stopped using their equipment was because the felt that now understood their soil moisture well enough with the equipment and were confident they could schedule irrigation without it.

Nutrition

Soil and leaf analysis were the most common tools growers used to decide what and when to fertilise their mango trees. Ag department recommendations, Experience, orchard history and consultant recommendations were also used by some respondents.

Over 75% of growers routinely use soil and leaf analysis with 64% saying that they are able to interpret the results themselves.

However, confidence with the recommendations and interpretation made from these analyses and confidence in applying the correct amounts of nutrients for optimum production was the lowest of all the management practises surveyed (Figure 14).

Pest & disease management

Growers were asked to rate the importance and incidence of pests and diseases in their orchards. As expected, the importance of pests and diseases varied depending on the growing region.

Pest importance

Mango scale rated as the most important insect pest for Queensland growers, with over 80% rating it as either of major or moderate importance (Figure 7). Mango scale was the only insect pest which was rated by every grower from all regions with no "Not sure" or "Doesn't occur" responses.

Mango planthopper, Fruit fly, Mango seed weevil and Tipborers were next most important insect pests for Queensland growers. The rankings for Fruit spotting bug and Red shouldered leaf beetle were lower than expected. This is possibly due to the timing of this survey in relation to the incidence of these pests in mango orchards.

Burdekin respondents rated most insect pests higher in importance than the rest of the Queensland growers. This was particularly the case for mango planthopper and mango tipborer. Eighty three percent of Burdekin responses rated mango planthopper highly compared with 30% for the rest of Queensland. Sixty seven percent of Burdekin responses rated mango tipborer highly compared with 30% for the rest of Queensland.

Figure 7. Importance of the major mango pests for different mango growing states. Figures are the percentage of respondents who rated the major pests as either major or moderate

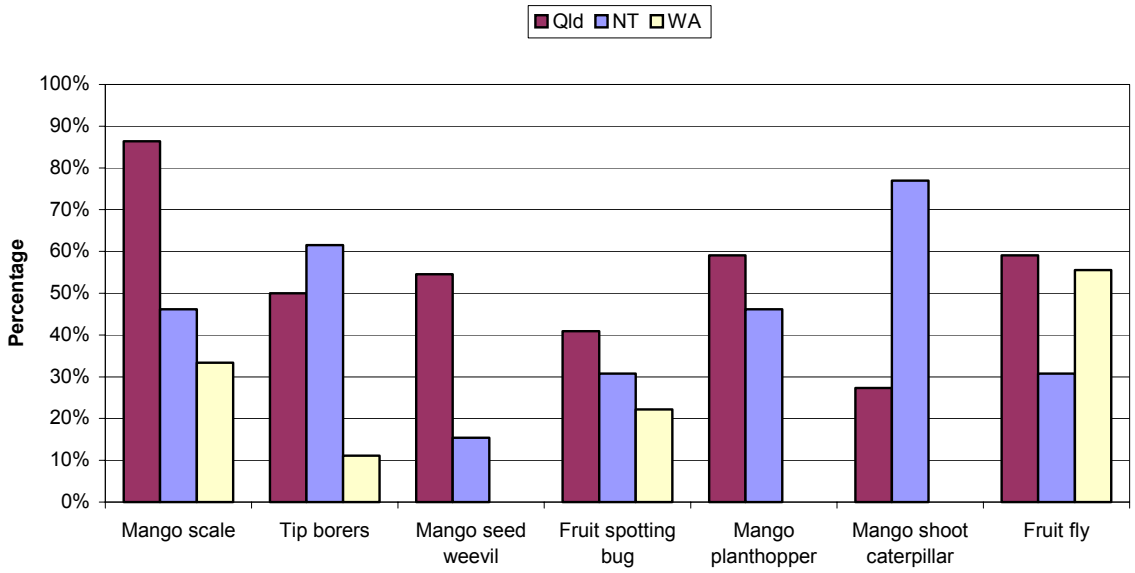
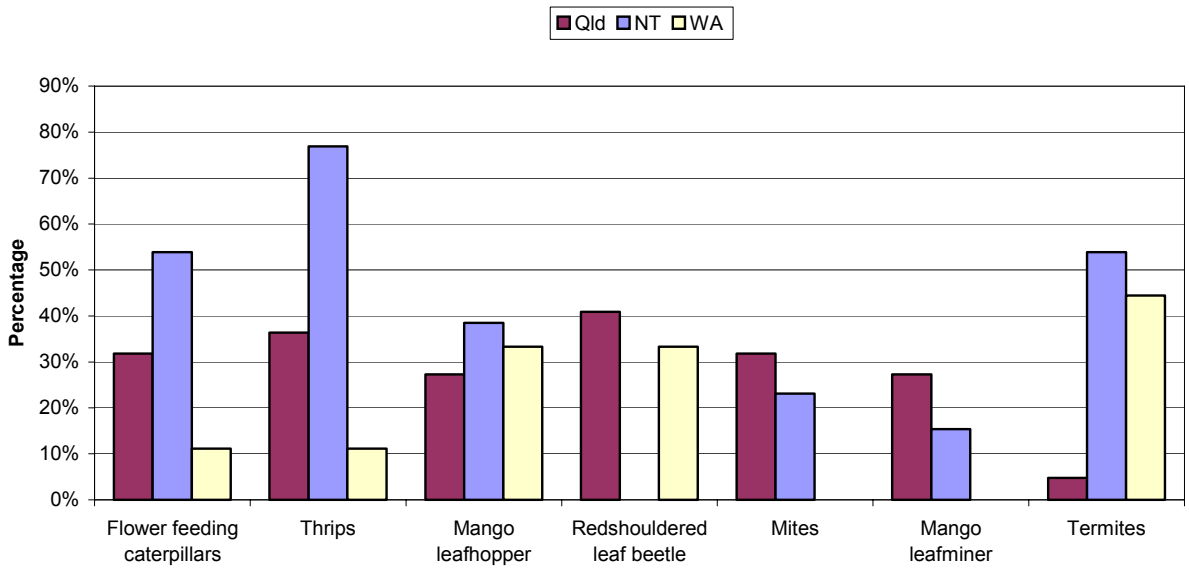


Figure 8. Importance of the minor mango pests for different mango growing states. Figures are the percentage of respondents who rated the minor pests as either major or moderate



Thrips were the most important pest problem for NT growers with 77% rating them of major or moderate importance. Termites and caterpillar pests including mango shoot caterpillar, mango tip borer and flower feeding caterpillars were also considered important pests for NT growers. Thrips and termites received no "Not sure" or "Doesn't occur" responses from NT growers possible due to their importance as pests.

WA growers considered most insect pests of minor importance. The only exception was fruit fly with 56% of respondents rating if of major or moderate importance. All of the responses from WA growers rated Mango seed weevil, Mites and Mango leaf miner as either "Not sure" or "Doesn't occur" while 89% rated Mango planthopper similarly.

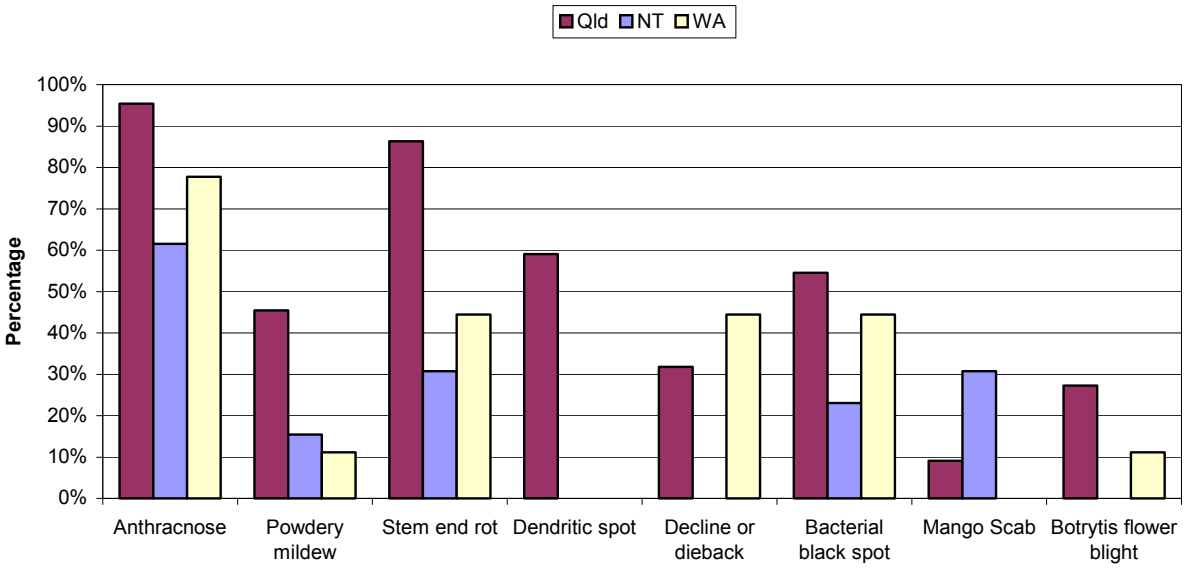
Importance of disease

Queensland growers considered most diseases higher in importance than growers in other states.

Anthracnose was considered the most important disease across all growing regions (Figure 9). Ninety one percent of Queensland respondents rated it of major importance. In comparison, only 38% of NT growers and 33% of WA growers considered it of major importance. Surprisingly, 23% of the respondents from the NT rated anthracnose as either "Unsure" or "Doesn't occur". All of these growers were from the Katherine region.

Queensland growers considered Stem end rot as a significant disease with 86% rating it of major importance. In contrast, only 31% of NT and 44% of WA respondents considered this disease of either major or moderate importance.

Figure 9. Importance of the mango diseases for different mango growing states. Figures are the percentage of respondents who rated the diseases as either major or moderate



Dendritic spot was only considered important by Queensland growers with 59% rating it of either major or moderate significance. Surprisingly, over 85% of NT and WA growers rated dendritic spot as either "Unsure" or "Unknown".

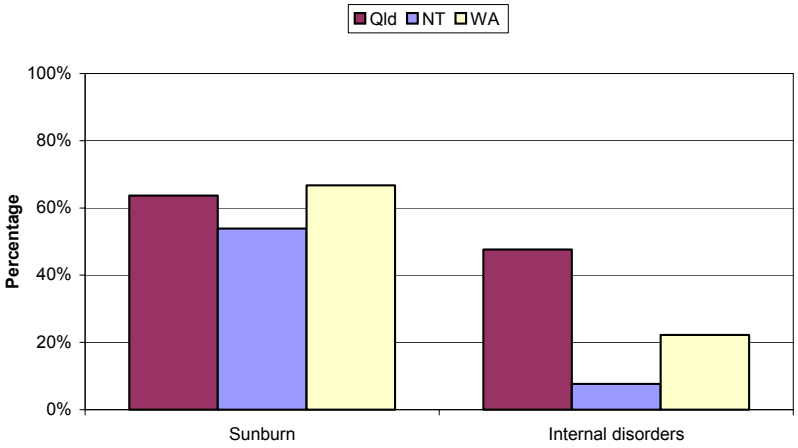
Powdery mildew and Bacterial black spot were important for some Queensland respondents with the later also important to some respondents from NT and WA. Some NT respondents regarded Mango scab important. Decline or dieback was important to some growers from Queensland and WA.

These results probably reflect the low incidence of these diseases during the past few mango growing seasons. If these diseases had been prevalent, they may have been rated of higher importance for this survey.

Importance of disorders

Sunburn was moderately important to growers from all growing regions (Figure 10). For NT and WA growers, sunburn was second only to anthracnose in importance so far as fruit quality was concerned. Internal disorders were of more importance to Queensland growers.

Figure 10. Importance of the mango disorders for different mango growing states

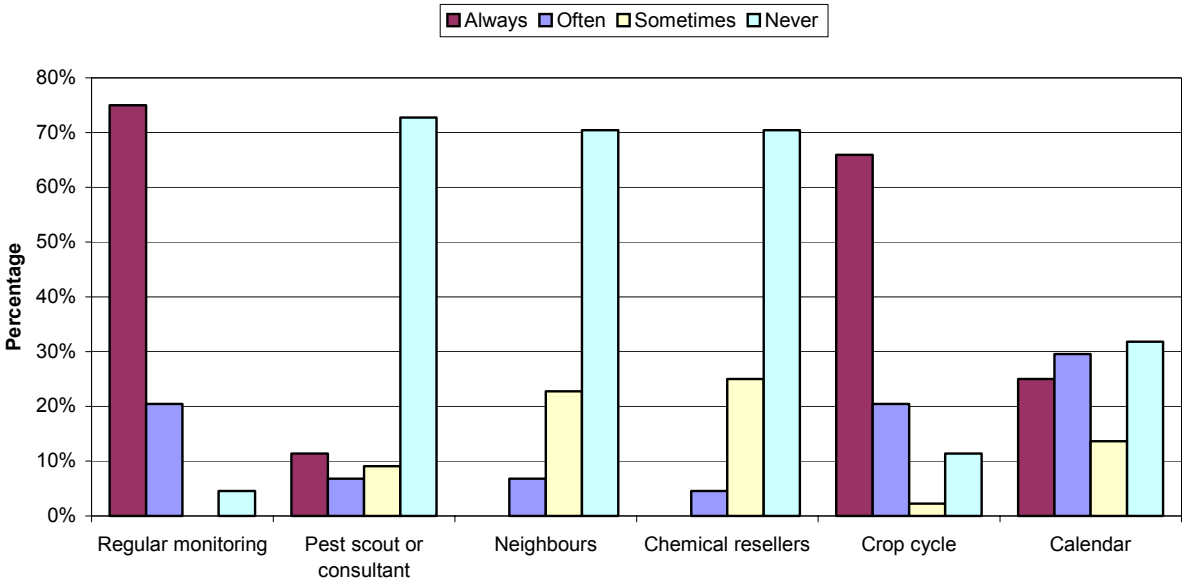


Deciding when to spray

Regular monitoring and the crop cycle were the most frequent methods used to decide when to spray and with which chemical. Using a "Calender" spray program ("I spray every 2 weeks with a fungicide") was also a popular method of deciding what and when to spray.

Pest scouts or consultants were used by a small percentage of growers (27%) but a significant number of respondents (> 70%) said they never them or Chemical resellers or Neighbours to decide when to spray.

Figure 11. How spray decisions are made for the mango orchard



Pest management program

A small number of actual spray records were collected during the course of the survey but only from Queensland growers.

Amistar®, mancozeb and copper were widely used with over half of those that responded to the survey using Octave® as well. Growers averaged 8-9 applications of mancozeb and 4-5 applications of copper annually. One application of Amistar® and 2 sprays of Octave® were applied.

Supracide® (methidathion) and carbaryl had the most common insecticide usage followed by dimethoate. Surprisingly, the use of Applaud® was low despite the high ranking given to the importance of mango scale.

Growers were given a list pesticides commonly used in mangoes and asked to classify them according to mode of action. While many growers found this question difficult, most provided answers (Table 5).

Table 5. Classification of commonly used insecticide and fungicides in mangoes

Chemical	Broad Spectrum	Targeted	Protectant	Curative	Systemic
Insecticides					
Applaud®	0%	36%	5%	5%	16%
Carbaryl	50%	18%	14%	11%	7%
Chlorpyrifos	41%	16%	18%	11%	5%
Dimethoate	36%	30%	14%	9%	36%
Endosulfan	43%	20%	11%	5%	0%
Supracide®	48%	9%	5%	14%	25%
Fungicides					
Amistar®	25%	14%	25%	25%	41%
Copper	20%	14%	64%	5%	0%
Mancozeb	27%	11%	66%	5%	0%
Octave®	11%	20%	36%	45%	16%

Spray application

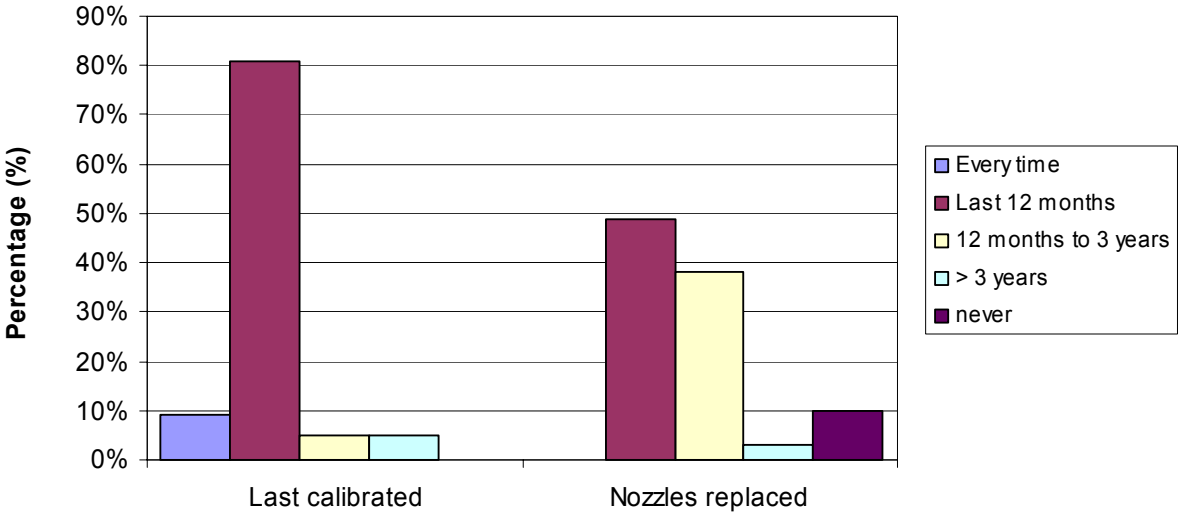
Growers were asked a series of questions relating to sprayer type, calibration and application. For the purpose of this survey, “Air blast” sprayers were classified as those that used nozzles to produce droplets and then used a large fan to propel these droplets into the tree. A “Mister” or air shear machine used the airflow of the fan to both create droplets and propel, them into the tree.

Ninety one percent of respondents were using Air blast machines for pesticide application. Orchard misters represented only 2% of the responses. Several growers used “Vertical

booms" which were made up of a number of individual nozzle and fan units mounted on a vertical boom and one grower used an "Oscillating boom" sprayer.

Figure 12. Air blast orchard sprayers (left) were the most popular unit used by mango growers. Vertical booms (right) have become more popular in recent years as growers seek better coverage, penetration and ultimately better pest and disease control.

Figure 13. Timing of spray calibration and replacement of spray nozzles



The majority of growers (81%) said they had calibrated their spray unit in the last 12 months. Most growers had changed their nozzles either in the last 12 months (49%) or in the last 12 months to 3 years (38%).

There was significant variation between growers in the spray volumes being applied per tree. Unfortunately, not enough detailed responses were received from growers to accurately allow comparison of spray volumes with canopy areas.

Spray volume applied per tree ranged from 4.5 to 12.8 litres. The pH of the water being applied ranged from 5 to 8 with average pH range being 6.9 to 7.6.

The main herbicide application method is a boom spray with a small number of growers spot spraying. The average swath width was 2.5 metres but did vary depending on canopy diameter. Between 200 and 400 litres per hectare were the most common herbicide spray volumes.

Integrated pest management

Growers were asked what the term "Integrated pest management" meant to them, whether they believed they applied on their farm and if so how did they do it.

While the definition of IPM varied considerably between growers, there were several common themes amongst them. These themes included:

- Monitoring pest and disease levels and only applying control measures when threshold levels were reached
- The combined use of a range of biological, cultural and chemical control measures to reduce pest and disease levels and enhance beneficial activity

Some examples of the responses given to this question are listed below.

- Combining crop monitoring, pesticide spraying, predator & parasite encouragement, canopy management, nutrition & irrigation to achieve the best economic & environment result
- Identifying and monitoring for pests and spraying only when a set threshold is reached and using the softest chemical available or predators available
- Using available methods to develop an IPM plan including pruning trees to remove dead wood & leaves to reduce disease, monitoring, selecting pesticides to specifically support biological pest management and rotating pesticide groups to minimise pest resistance.

Over 72% of respondents said they believed they used IPM on their farm. Not surprisingly, all measures related to insect control rather than disease control. The things growers said they did on their farm as part an IPM strategy included:

- Minimal spray and the use of softer chemicals to control pests and allow beneficial insects to build up
- Regularly monitoring pest levels

Only one grower said they used cultural control measures such as pruning trees to remove dead wood and reduce residual pest populations such as mango scale.

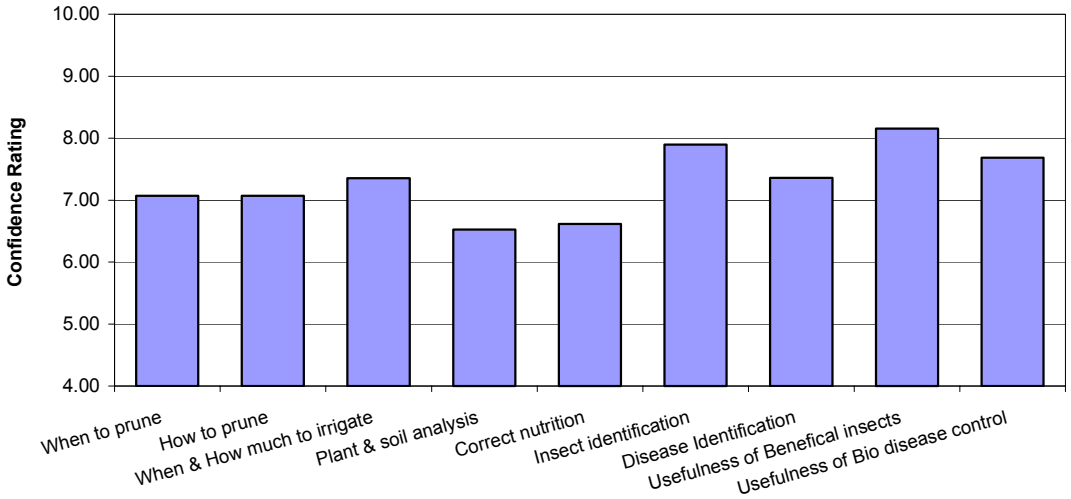
Attitudinal responses to production practises

At the end of each orchard management section of the survey, respondents were asked to rate how confident they were in the decisions they made relating to specific management. A scale of 1 to 10 was used with 1 being "Not confident" and 10 being "Very confident".

The responses indicated that growers were most confident with insect identification and the usefulness of beneficial insects and biological disease control for pest and disease management. (Figure 14) They were least confident in the recommendations made from plant and soil analysis, in applying the correct balance of nutrients for optimum production and in knowing when and how to prune for optimum production and fruit quality.

There were some regional variations in the responses for some management practises. These variations are presented in Figure 15 and Figure 16.

Figure 14. Average grower confidence rating relating to orchard management



In most cases, Queensland growers were more confident with their decisions than growers in either NT or WA. They were more confident with their pruning decisions particularly in knowing when to prune. They were also more confident with the identification of pests and disease than growers from the other states.

Figure 15. Grower confidence rating general orchard management practises by growing state

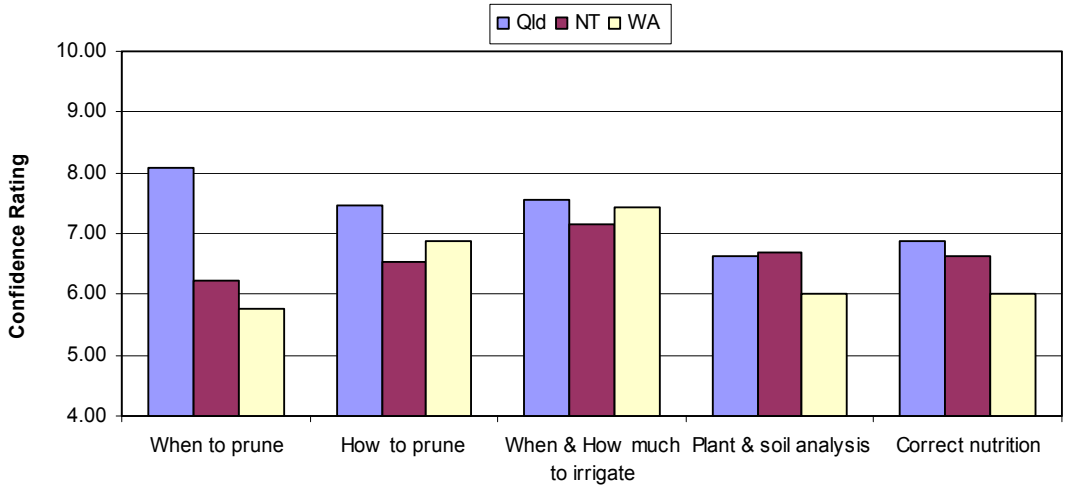
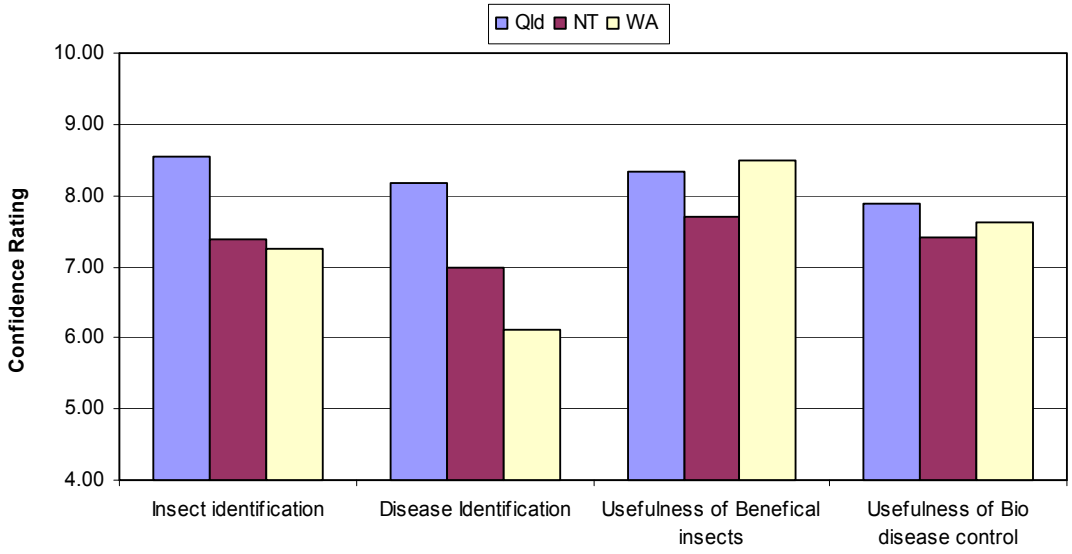


Figure 16. Grower confidence rating general pest and disease management by growing state



Harvesting

Internal flesh colour (91%) was the main was the main method used to decide when to harvest and whether fruit is mature followed by blush (36%) and dry matter (30%). Fruit shape, heat sums and skin colour were mentioned by a small number of respondents.

Labour: Sixty four percent of respondents pick their own fruit with 36% using contract pickers to harvest their orchards. This can be influenced by harvest season particularly in years when the crop is spread out over a number of weeks necessitating 4 to 5 'picks'.

Most picking staff are employed on a contract basis either per bin or crate or kg. Rates varied considerably between growers and growing regions.

Only 27% of respondents used bonus systems with their harvesting staff. The most common system used was a bonus if the pickers or other staff stayed until the end of the harvesting season.

Two growers had productivity bonuses which related to the amount of fruit picked per day based on a threshold level. Once the picking crew or individual had picked a certain amount they got a bonus. For example, if a picker harvested more than 90 trays per day they got an extra $1.50 per tray picked.

Harvesting systems: Of the 45 growers surveyed, 73% used harvest aids or destemming in the field to desap fruit while 25% pick the fruit with stems attached and bring them to the packing to be desapped. The percentage of growers desapping in the shed is continuing to fall as many are moving to harvest aid systems to reduce picking and desapping costs.

The average volume of fruit picked per day with a harvest aid system was much higher (2600 trays) than for fruit picked with stems attached and desapped in the packing shed (1000 trays). However, several orchards surveyed who desap in the packing shed, harvest the same volume of fruit as the largest volume orchards using harvest aid systems.

The percentage of fruit left unpicked in the field averaged between 7 to 9% in a good or average year and increased to 16% in bad year. The amount left behind ranged from 0 to 50% in some several cases. Only 2 growers said they picked all their fruit leaving nothing behind in the orchard using fruit removal as control measure for pests and diseases such as mango seed weevil.

The reasons for leaving fruit in the field were many and varied. Low prices, labour shortages, fruit quality (overripe or damaged) or just missed by the pickers were the most common responses. Poor market prices may have had more of an impact due the 2004 crop being the largest crop ever harvested by the Australian mango industry.

Harvest aids or destemming in the field: Three harvest aid machines per orchard was average. The types of machines being used varied not only across orchards and regions but within orchards as well.

Some growers have modified cherry pickers to use as in field desapping machines. In these situations, the number of machines per orchard increases while the number of pickers has reduced. The data collected during the review meetings suggests these systems are more efficient relating to both cost and quality.

The average number of pickers per machine was 5 to 6 with 3 additional people involved with the non-picking side of harvest (supervising, desapping, transport of fruit to the packing shed etc.).

The amount of fruit harvested per day varied between 2000kg (286 trays) to 50,000kg (7140 trays) due to the variation in the size of the orchards surveyed. The average ranged between 17,000kg (2400 trays) and 19,500kg (2800 trays).

Bulk bins, either 300kg (44%) or 500kg (35%) were the main container used to transport fruit to the packing shed. Only 21% of growers used field crates and this number appears to be decreasing each year. Bulk bins were usually transport to the packing shed using special designed trailers while field crates were transport using trucks or utes.

Destemming in the packing shed: The number of pickers used varied considerably from 2 to 200 due to the variance in the size of orchards and packing shed surveyed. Picking crews averaged between 4 to 5 people per crew with 2 to 4 non-picking support staff.

The volume of fruit harvest per day was again variable ranging from 700kg (100 trays) to 50,000 (7140 trays). The average ranged between 4460kg (640 trays) and 9200kg (1314 trays)

Fruit crates (92%) were the main container used to transport fruit with stems attached to the packing shed. Only one respondent used bulk bins. Trucks or utes were again the main vehicles used to transport fruit to the shed.

Packing shed

Over 70% of respondents packed their own fruit.

Costs of packing: The costs of packing a tray of mangoes varied from $3.00 to $8.25 per tray, with average cost of $6.60 per tray. There were too few responses to compare these costs regionally. In most cases, they included all the costs incurred after the fruit was delivered to the packing shed such as grading, packing, tray & liner, cooling, freight to marketing & selling costs.

Staff: The variation in the size of the packing sheds surveyed made it difficult to comparatively look at staff numbers used in postharvest operations.

Desapping staff accounted for 31% of the labour in packing sheds which desapped in the shed compared to 10% in packing sheds which used harvest aids to desap in the field. Packing sheds which desapped in the field using harvest aids had 22% less staff on average than packing sheds which desapped in the shed providing a significant cost saving.

This was highlighted in our extraction workshops. Mango growers suggested cost savings of 30-40% in picking and desapping when they compared shed desapping to field desapping in their orchards.

Despite these apparent costs savings, some growers remain committed to desapping in the packing shed because of perceptions of poor fruit quality being out-turned with harvest aid machines.

Grading, packing and stickering operations accounted for 55% of staff employed in the packing shed. The remainder of staff were involved with palletising, cooling, box making or consigning fruit.

Labour hire and management: Most respondents (74%) looked after the hiring of labour for their farm and packing shed themselves. The costs involved with employing and managing a person varied dramatically between respondents. Some respondents were unable to put a figure on the costs

Thirty six percent of respondents used labour hire services including Grunt Employment Service and Backpacker hostels. The labour hire services looked after all the paperwork involved with hiring and managing employees including paying them, as well as Workcover, payroll tax, superannuation, taxation, payroll administration and public liability. They charged between $2-4.00 of the hourly rate paid to the employee for their services.

Backpacker hostels and employment agencies provided staff but did not look after any of the paperwork involved with hiring and paying them.

Postharvest chemical treatments: Chemical treatments applied to mangoes postharvest varied depending on growing region.

Packing sheds in Queensland were the only ones to use heated dips to control disease. Seventy nine percent of respondents used a heated dip. Spin Flo® (carbendazim) was the only chemical used in the hot dips with 2 packing sheds using only heated water as disease control.

Twenty one percent of sheds in Queensland used only Sportak® (prochloraz)as a non-recirculated spray for disease control.

Packing sheds in the Northern Territory and Western Australia relied on Sportak® as the postharvest chemical treatment to control disease. Most of these packing sheds (93%) applied Sportak® as a non-recirculated spray. However, 2 packing sheds indicated they used Sportak® as a dip which is contrary to the label directions.

Seventy seven percent of packing shed in Queensland and the Northern Territory were applying postharvest insecticide treatments. No packing sheds from Western Australia who responded to the survey were treating fruit with an insecticide treatment postharvest.

Fifty percent of packing shed respondents applied their insecticide as a non-recirculated spray, 35% a recirculated spray and 15% as a dip. Sixty five percent of packing sheds applied dimethoate for insect control with the remaining 35% using fenthion.

Application method would be influenced by the chemical applied as fenthion is only registered as a non-recirculated spray. Not enough responses were received to compare the application methods used for dimethoate alone.

Sixty percent of packing sheds which applied both a prochloraz and an insecticide treatment, mixed them in the same tank. The remaining 40% applied the two chemicals separately.

Disposal of waste water: Respondents were asked how they disposed of their waste water from their packing sheds including water from their hot dip, cold fungicide and insecticide treatments.

In most cases, all water, with the exception of water used for the insecticide treatment, was drained into the orchard either from a collection pit or dam or directly from the packing shed. Only 1 packing shed treated their fungicide waste water with a neutralising agent (lime) before spreading it on the ground in their orchard.

Water mixed with insecticide was usually pumped into a holding tank before having a neutralising agent added (usually lime) and then sprayed out on the ground in the orchard.

Only 1 respondent didn't spread their waste water back onto their orchard, pumping into a holding dam before irrigating a wooded lot.

Traceability system: All packing sheds had some sort of traceability system in place. Specific traceability software being used included Hortilink and Harvest Tracemaster. Quality management systems (FreshCare & SQF2000) and Interstate Certification Assurance systems (ICA 02 & 19) were also listed as traceability systems used by mango packing sheds.

All systems used listed carton labelling as the primary method of enabling traceability from the market back to the orchard.

D. Discussion

Business management

Grower's appreciation of their costs of production and benchmarking their management standards against industry standards are not happening for three reasons

- They don't know their actual costs
- They don't see value in sharing information &
- They continue see other mango growers as competitors

Because many mango growers don't appear to know their actual true costs of production or breakeven points it is possibly making it hard to set employee bonuses at a level that will attract and keep staff while not adversely affecting profitability.

There still appears to be a lack of adoption of improved practises and information from current and past research amongst the wider industry. This issue was highlighted during the "Improved technology transfer within the mango industry" project (Holmes, R.J., 1999).

Evaluation from Better mangoes project and Mango training workshops has shown the benefits of working closely in collaboration with mango growers and packing sheds. They have dramatically increased information and adoption of new and existing research amongst industry participants.

The experience from these projects needs to be expanded across a wider cross section of industry. This will be difficult with limited time, resources and the spread of the mango industry. The use of the Internet to deliver information and training needs to be developed, not just for mango growers but supporting industries such as chemical resellers and transport companies.

Orchard management

Nutrition: The area of mystery and secrets. Growers will not share their information on nutrition, because they consider it to be the major determinate of maximum productivity and good fruit quality. But they have a low level of confidence in their ability to determine the best nutritional program and have a high request for more information.

Nutrition has the biggest impact on productivity and fruit quality and growers are aware of this ranking it the most important of all the management practises. This survey has shown the need for some concentrated work in this area.

Canopy management: Pruning had a low score for confidence in decision making and low importance for optimum production and fruit quality. However, there was only a moderate demand for information relating to canopy management. Because of the significant impact canopy management has on the productivity of an orchard.

It is also an important area when it comes to pest and disease control, particularly reducing inoculum and residual pest populations. Inoculum reduction research has focused predominately on complete removal of pruned material from under the canopy. Systems which sweep dead material out into the inter-row for mulching which then directs the mulched material back under the tree need to be further investigated for their value in reducing disease inoculum levels in an orchard.

Variation in the usage of growth regulators in mangoes suggests a lack of knowledge about their use and effect. Improved nutrition and their impact on tree health, particularly on pest and disease levels are areas where future work needs to focus. With only one long term usage study being conducted, it appears growers are still unsure how to make the best use of these products.

Irrigation: There still appears to be confusion about the correct amounts of water to apply to mango trees to achieve optimum production and fruit quality. The increased usage of moisture monitoring equipment has help improve growers decision making about timing but has not addressed the key questions of how much and how often.

Irrigation is an emerging issue for future R&D work. Recent funding has focused on increasing the use of moisture monitoring equipment to improve water sue efficiency. Future work should examine the use trickle irrigation systems in mangoes and the efficiency of micro sprinkler systems, particularly related fertigation. This is an area were many overseas mango growing countries, particularly South Africa, Israel and Brazil, have made significant gains in productivity and fruit quality.

Pest & disease management: Burdekin growers rated most insect pests higher in importance than growers from all other growing areas. This response is possibly due to the additional exposure from projects or training in the correct identification of pests and diseases.

The low ratings for anthracnose and stem end rot by mango growers in NT & WA is surprising considering the impact these disease are having on fruit saleability in both the domestic and export markets.

This survey has highlighted the improved adoption that can be achieved as a result of specific project work such as activities conducted during the Mango Plant Protection project - Phase 1, the Mango Training workshop series and the Better Mangoes supply chain project.

Growers in all growing regions believe that beneficial insects and biological disease control would be very useful in keeping insect pests and diseases from causing damage

There were some interesting contradictions in the information growers wanted, the sources they valued and how often they used those sources in making spray decisions. Other growers were rated as an important source of information but not on deciding when and what to spray. The results were similar for Chemical resellers with over 70% of respondents saying they never used them or other growers to make spray decisions.

Harvest & Packing shed

Labour: Only a small number of respondents had bonus systems for field or shed staff. Several vegetable packing sheds in the Burdekin have indicated that they only plant additional plantings at certain times of the year to keep their permanent workers employed otherwise they lose their skilled, trained staff (Evan Shannon, Charlie De Dominico pers. comm.)

One important questions relating to labour is that if labour costs are significantly reduced with the use of harvest aids as has been identified in this survey and the Extraction workshops, why hasn't all of the industry switched over to them. Are there still significant concerns over fruit quality issues with harvest aids or are the cost savings not as significant as being reported?

Harvesting: The efficiency of harvest aids requires further work. Particularly comparing multi person machines to cherry pickers with only one picker and the volume of fruit per day relating to number of pickers. There is also a strong need to assess relevant quality issues with in-field desapping as well.

The project didn't investigate grower's perceptions of the impact of postharvest quality issues such as disease breakdown and skin browning although these issues still need to be addressed within a D&E strategy. An example of this is mango skin browning. New chemicals are now available which possibly need to be evaluated in a similar way to those during the skin browning project (FR440: 1997).

E. Conclusion

The results of this production review survey have identified a number of opportunities for future research, development and extension activities that could improve fruit quality, productivity and ultimately, profitability. These project opportunities include the following:

1. Benchmarking project working with mango business to identify areas to improve business efficiency. This project could start with the development of an appropriate computer based farm diary recording system similar to the Macman program.
2. Unlocking research. Developmental research using on-farm trials is the ideal way to improve adoption and understanding of key orchard management concepts including canopy management and nutrition. Similar projects such as the "Unlocking Lychee" project have been successful in improving adoption and practise change amongst growers.
3. Investigating the use of the Internet to deliver information and training to remote or skilled growers. The Australian mango industry research compendium project is one of the first steps in developing On-Line training and specific information more available.
4. Analysis of Harvest aid systems focusing on labour efficiencies and fruit quality issues. Single and multi-person systems need to be benchmarked to establish the main requirements for harvesting systems to deliver labour efficiencies without adversely affecting fruit quality. The Mango skin browning project (FR440, 1994-1997) needs to be revisited focusing on new chemicals and current fruit quality issues.

5. Independent review of the packing shed to identify efficiency areas and WHS issues. Time-in-motion studies within packing sheds have delivered improved labour efficiencies and significant savings in industries such as bananas.

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4. Regional RD&E Extraction Workshops

A. Methodology

Workshops were held in six of the major production areas across Australia to seek growers input in identifying critical areas that impact on profitability, yield and quality in the production harvesting and packaging of mangoes. Growers were asked to concentrate on maximising yield per hectare, but not necessarily increasing total production. The focusing questions were

- "How would you maintain your production at 45,000 trays, if you reduced your number of trees from 5000 down to 3000 trees? How would you make your trees work harder for you?"
- "The average yield per tree across Australia ranges between 2 trays and 8 trays per tree. The estimated theoretical yield for mango ranges between 20 and 60 trays per tree. How can the productivity be increased?"
- "Your targeted production is 45,000 trays. The difference in harvesting costs between a farm with 2000 trees compared to a farm with 14,000 trees is approximately 700%. How can profitability be improved?"
- What different orchard management practices would you need to implement to increase the shelf life of your product from 15 days (domestic) to 45 days (export). [Shelf life expressed as from the time the fruit is packed in the box].

To assist growers in this task, the production cycle was broken up into four segments;

1. Establishing an Orchard
2. Harvest to harvest
3. Harvest
4. Packaging Shed.

Within each of these segments, the issues and key points that they considered impacted on productivity, profitability and fruit quality were documented. In the majority of the meetings an assessment of each issue was rated in regards to;

- Impact of the issue on productivity, profitability and fruit quality,
- Knowledge. Growers assessment of their knowledge of the issues and
- Confidence. How confident the growers were about their knowledge and if they considered that more information is needed to be generated (RD&E).

Data from all workshops are presented in Appendix II. A summary of the Critical Points and questions from this data are in Appendix III.

To assist in eliciting from the data collected, what areas of research would provide the highest return for industry investment, an impact assessment analysis (Appendix V) was conducted based on;

- Percentage cost of production.
- Impact on fruit quality
- Impact on yield
- Potential improvement from RD&E
- Need to improve knowledge
- Need to improve adoption

- Need to improve Information.

A rating scale of 1 to 5 for each criterion was applied. Assessment data from the workshop was interpreted into the impact assessment for Growers Appendix V Table 10, where as a detailed assessment by production practice against phenology timing was made by service provider researchers Appendix V, Table 11. Computations used to identify priority differences are presented in Appendix V, Table 12.

B. Results (Table 6 and Table 7, Appendix II and Appendix III)

The results from each of the regional workshops are presented in Appendix II and listed in Appendix III is an amalgamation across all regions of the critical issues and the resulting focusing questions. Table 6 is a further summary of the key issues.

Table 6. Summary of Key Issues Across the Four Production Cycle Segments.

Orchard Establishment	Harvest to harvest	Harvest	Packing Shed
• Variety • Rootstock • Orchard Design • Tree Architecture • Windbreaks • Weed control	• Labour • Nutrition • Irrigation • Disease control • Insect Control • Canopy Management • Flushing • Panicle development • Pollination • Fruit set • Fruit retention	• Labour • Crop Forecasting • Fruit Maturity standards • Harvest aids • Standard fruit defects descriptions	• Labour • Post harvest treatments • Computerised grading systems

Orchard Establishment

In the establishment phase of an orchard (dirt to first harvest), the most critical issues of concern were;

- Variety
- Rootstock
- Orchard Design
- Tree Architecture
- Wind breaks
- Weed control

Outside of the variety, rootstock and weed control strategies, there was general consensus that limited research was needed during orchard establishment. Varieties and rootstock are

covered in a separate review on genetic improvement, however it is important to identify that growers considered these as priority issues.

Regionally based extension activities such as grower surveys to identify optimum orchard orientation and canopy management at the early stages of plant growth targeted at the maximisation of yield, fruit quality minimise sunburn on tree and fruit, and labour minimisation were considered most appropriate for the other issues. Similarly generic information should be provided for each region on the selection and planting requirements for wind break tree species. Also what are the positive and negative impact of wind breaks in regard to beneficial insects, disease management and moisture loss for neighbouring mango trees?

In those regions where pre-emergent herbicides are used (Kununurra and Burdekin), appropriate registration of these herbicides may need to be investigated. Up to six application of the post emergent herbicide, glyphosate was considered expensive, time consuming and possibly detrimental to the plant.

Harvest to Harvest

Analysis of this phase of mango production has revealed many common but difficult questions that focused around the inconsistent and poor performance of the Australian mango. Issues such as irrigation, nutrition and pruning focusing on maximising the possibility of flowering, pollination, fruit set, fruit retention, yield and fruit quality were identified. Disease management in all regions including Katherine was considered to be the major constraint to expanding market development on both the domestic and export markets as a result of fruit breakdown in the supply chain.

There was a consistent request that regionally based solutions and recommendations be developed, however the majority of issues were common across all regions.

The incidence of Sunburn (tree and/or fruit) in the majority of regions was considered to contribute to between 20 and 30% fruit loss in the field.

Questions about minimising labour inputs at all stages, focused many growers into greater usage of technology (eg. moisture monitoring equipment) but they were consistently concerned about the follow up service that these companies provided.

The broader issues of finding, training, retraining and retaining labour were always seen as a major problem.

To analyse the complexity of the production systems, the key issues were broken down into management options in agronomy/physiology, plant protection and the interaction of all these issues on the overall aim. This identified a range of focusing questions (Table 7).

The major aim is the have a management systems that can ensure within a block, uniform flowering, maximum fruit set and retention and uniform maturity. This will reduce the number of harvest passes and maximise harvest labour efficiency. The ideal is to have sequential blocks for harvest across the farm. Next is to have plant protection practices that ensure fruit shelf life and market access.

It was acknowledge that many of the agronomic options interact and because of the nature of mango, this research is difficult to achieve.

Table 7. Focusing Questions Within The Harvest To Harvest Production Segment

<table>
<tr><td></td><td></td></tr>
<tr><td>Agronomy/
Physiology</td><td>
2. How can agronomic practices maximise productivity and minimise labour requirements
3. What is the critical time to prune (by region & variety) to achieve
a. Optimum flush development.
b. Maximum flower development.
c. Maximum Fruit Quality
d. Minimum disease development
e. Optimum tree structure to maximise labour efficiency
4. What are the critical issues with pruning?
a. Optimum canopy area to light capture
b. Carbohydrate levels within the plant
c. Pruning methods
d. Sunburn management
4 What are the optimum nutritional requirements for mango (by region and variety), to achieve maximum yield, fruit quality and fruit shelf life?
Inputs
• Timing
• Amounts
• Application methods
Outputs
• Pollen viability & % flower sex ratio
• Fruit retention
• Fruit quality
• Lenticel spotting
• Disease levels
5 What are the optimum irrigation requirements for mango (by region and variety), to achieve maximum yield, fruit quality and fruit shelf life?
Inputs
• Timing
• Amounts
• Application methods
Outputs
• Flush
• Flowering
• Fruit retention
• Fruit quality
• Shelf Life
6 What are the appropriate monitoring tools and systems available to determine the nutritional and water status in a mango
</td></tr>
</table>

<table>
<tr><td></td><td>plant?
7 What strategies can be used to manipulate flushing patterns?
a. Chemical (Plant Growth Regulators, hormones, etc).
b. Canopy management
c. Root pruning
d. Sintering
e. Nutrition/Irrigation
f. Root stocks
8 What is the optimum canopy area to fruit ratio for mango (by region & variety) to deliver maximum yield and fruit quality?
9 What are the key principles to achieve maximum pollination in KP?
10 What are the management options that minimise sunburn?
a. Orchard orientation
b. Canopy/light interception ratio
c. Pruning strategies
d. Pesticide applications.</td></tr>
<tr><td>Plant Protection</td><td>1. What are the economic threshold levels of insect pests of mango (by region and Variety)?
2. What are the IPM practices required to manage insect pest population (by region by variety)?
3. What are the economic threshold levels of the various diseases of mango (by region and Variety)?
4. What are the IDM practices required to manage disease (by region by variety)?
5. What is the appropriate application technique for the various diseases?</td></tr>
<tr><td>Interactions</td><td>1. What is the interaction between the various management options to manipulate flushing to ensure uniform flowering?
<table><tr><td></td><td>PGR</td><td>X</td><td>Y</td><td>Z</td></tr><tr><td>Pruning</td><td></td><td></td><td></td><td></td></tr><tr><td>Nutrition</td><td></td><td></td><td></td><td></td></tr><tr><td>Irrigation</td><td></td><td></td><td></td><td></td></tr><tr><td>Climate</td><td></td><td></td><td></td><td></td></tr></table>2. What is the interaction between plant nutrition and disease incidence?</td></tr>
</table>

Harvest

The dominant issue discussed during the harvest process was labour, both cost and availability. Harvesting systems that can improve labour efficiency in the field whilst minimising the impact of harvest on fruit quality were identified as critical issues by participants.

The use of harvest aides were recognised as being the most significant method of reducing labour within the paddock as well as minimising the impact of sapburn and skin browning on fruit quality. However the considerable variation in harvest aid design identified a need for an assessment of the do's and don'ts when designing these units.

The new cherry pickers units were acknowledge as have significantly greater benefits over other units in regard to labour efficiency and fruit quality, but issues of training, work place health and safety and capital cost were the draw backs.

The main RD&E issue identified during the harvest process was maturity: how to measure it, how to predict starting times for harvest and seasonal production volumes. The main points from these discussions were:

- A strong desire to have a quantitative measure of fruit maturity for harvest that relates to the consumers' expectation of fruit flavour and shelf life. Growers felt that the dry matter & flesh colour measure that are being used currently are insufficient to ensure reliable results. The quality standards and principles adopted by the white table grape industry were continually quoted as being a practice that the mango industry should adopt.
- The crop forecasting system that has been developed in Northern Territory should have the data set broadened to evaluate the potential across all the industry. Not all districts in the initial test need to be included, only the extremes of the production window such as Mareeba and Bundaberg.

Pack Shed

The practices within the packaging shed and shed design varied widely and there appeared to be little guidance from the growers as to what were the critical issues, except for the desire to reduce labour. As the move to harvest aids increase, the removal of de-sappers in the packaging shed, has been acknowledged as a major labour saving exercise. However there were lingering concerns that stork removal at harvest could be reducing the shelf life of fruit and an increase level of post harvest diseases. This was based on the significant amount of sap loss immediately when the stork is broken away from the fruit.

Many growers are moving to computerised bar coding and in some cases in-line grading equipment. However the capital investment required for the short harvest period is impeding the uptake of these practices.

With labour being the major issue in the packing shed, RD&E needs to focus on labour efficiency strategies such as time in motion studies to identify areas and operations within packing sheds that can be modified or mechanised to save labour. Similar studies in banana packing sheds have resulted in significant improvements in productivity

5. RD&E Business Case

A. Discussion

To rationalise and focus the outcomes from the extraction workshops and grower survey data, a range of key strategies and key issues were identified. This process has lead to the development of a number of focusing questions that would deliver the outcomes that growers were wanting. Through the use of the impact assessment analysis, (which introduced factors such as knowledge and confidence of past research and the impact of key issues on productivity, profitability and fruit quality) the activities were priorities and an over all research, development and extension plan has been developed.

Analysis of the key issues and focusing questions, together with the confidence and attitudinal responses from the benchmarking survey identified six key long term sub-strategies to address the over all intent of Strategy 3 and its four activities of the AMIA strategic plan.

These are:

Key Sub-Strategies.

1. High yielding orchards, designed to have blocks that can be harvested sequentially with a maximum of 2 passes, supplying quality fruit to targeted markets for a maximum period of time.
2. Pest management systems that use Integrated Pest Management principles to provide quality fruit to targeted markets, without the use of post harvest treatments.
3. In-field disease management strategies that ensure that fruit is robust enough to have 45 days shelf life and that reduces or removes reliance on post harvest treatment.
4. Production and harvesting systems that minimise labour requirements and costs of production and handling without negative impact on fruit quality
5. Fruit maturity standard and harvest prediction indices for each variety
6. Packing sheds and handling systems that maximise product throughput, improve fruit quality and systems that allow for product traceability.

B. Past and current research

A list of some of the past research and extension activities within DPI&F, NTDPI and CSIRO over the past fifteen years is presented in Appendix IV as well as a snap shot of project by work area. The majority of this RD&E has been funded within the agencies, with limited support from Industry and Horticulture Australia. The majority of funding during this period has come via ACIAR and regional economic development funding (both State and Federal sources). The unique characteristic of the ACIAR funded projects is that they have provided researchers the capacity to conduct investigative research into difficult issues. This started in the early nineties with the physiology/nutrition studies around which the current recommendations for canopy management irrigation and nutrition are based. Similarly, research projects on stem end rot and anthracnose have provided solid grounding for our current knowledge. The majority of recent ACIAR projects have had a strong post harvest disease focus, and physiology/agronomy issues have received limited attention, which is reflected in many of the questions being raised by growers.

There are a number of current projects running, three of which are funded through HAL and five with ACIAR/AusAID. A summary of these are presented in Table 9.

The project on crop forecasting, lead by Greg Owens, is an extension of activities that have been progressing for some time in the Northern Territory, and has just been extended for another term, to further refine the system.

All other projects have a strong plant protection and market access focus and have significant influence on the where the mango industry should invest their RD&E with HAL in the short term.

Disease management

Dr Lindy Coates and Dr Chrys Akem (Qld DPI&F) lead ACIAR funded projects on developing disease control strategies utilising mechanisms that stimulate the plants defence systems against disease development. Compounds that positively stimulate the plant's natural defences have been identified and are being tested. Nutrition also shows positive (increased calcium and silicon level) and negative (increased nitrogen levels) effects on the plant's capacity to fight disease. The current Chrys Akem (DPI&F) led component of HAL project, FR02050, identified that inoculum reduction strategies through out the crop cycle are an important management tool. These results coupled with a review of disease management research will results in comprehensive recommendations for future work as a further outcome of this project.

Insect management

Bruno Pinese's (Qld DPI&F) ACIAR/HAL project is showing positive results for the use of pheromones for monitoring and surveillance of red banded mango caterpillar and has also developed control options if this exotic pest threatens the production areas. FR02050 has developed insect pest and beneficial monitoring systems, and evaluated some options for reducing the reliance on broad spectrum insecticides. This project has exposed the problem of removing such insecticides from the spray program, in that Fruit Spotting Bug (FSB) will potentially become more prominent. Significant research on FSB has been conducted in other commodities and a wealth of knowledge is already available, but the ACIAR IPM project, will over the life of that project hope to resolve these concerns.

The introduction of the parasitoid for the management of mango scale (FR02050), from South Africa, has not progressed a smoothly as the researchers had hoped, and this is a critical area of research that needs to be completed.

The focus of research in two ACIAR/AusAID projects is on mango seed weevil, both from a field management and market access perspective. These projects are just starting and will possibly be funded for three years. A positive result in both areas is likely. This project will also provide excellent data on mango pulp weevil which is a major exotic pest threat to the Australian industry. Data on the pest life cycle, monitoring techniques, potential economic damage, and control strategies will be generated with these two projects.

C. Impact Analysis (Table 8 and Appendix V)

Grower Assessment

The analysis by growers of the potential impact of RD&E was grouped under the headings of field practices and harvest.

Disease management comes out strongly as the major focus of research and information needs in the orchard. This view was supported by the benchmarking survey. Other research areas identified as requiring additional investment are nutrition, canopy management and insect control. Limited or no investment is required in irrigation and the application of plant growth regulators.

For harvest practices, excluding labour, crop forecasting, fruit maturity index and improvement of harvest aids were all considered equally critical. In discussions with researchers (Mr Yan

Diczbalis), the fruit maturity index needs to consider dry matter, flesh colour but also be closely linked to heat units, which is also the basis behind the crop forecasting model. For this reason any further development in the crop forecasting model needs to include the development of a maturity index for each variety by region.

The major issues in the packaging shed, again excluding labour, focused on identifying practices to avoid post harvest treatments, and expanding the opportunities of computerising practices such as grading, bar coding etc. Avoiding post harvest treatments translates to greater management of the pest and disease issues back into the orchard.

RD&E Provider Assessment

An analysis of orchard practices aligned to timing of the plant and fruit development, was conducted by research staff. The broad headings of irrigation, nutrition, disease control, insect control, canopy management and plant growth regulators, were considered. The rankings were the similar to the grower's priorities. Disease management and nutrition were priority areas for consideration.

However a more comprehensive picture is exposed when analysed down to the various stages of crop development. Data presented is only the highest 20 rankings, number 1 being the highest priority.

a. Improved disease management is important in nearly all phases of crop growth and the need for better disease management skills together with improved access to research data with a comprehensive and ongoing technology transfer strategy to maintain best practice in disease management by all grower's in all areas is absolutely critical. This is confirmed in the grower survey data. Aligns to Key Sub-Strategy 2.

b. Although nutrition management over all is important, researchers are indicating, that a significant amount of the knowledge is already available, but just needs to be interpreted, and customised to region, soil type and variety. Customised information is required by industry. This has been confirmed in the extraction workshops, where growers are asking for regionally based nutritional recommendations. Results from the grower survey also considered nutrition a major issue. Aligns to Key Sub-Strategy 1.

c. Canopy management accounts for 4.6% of the production costs, and growers considered it as the third priority area, but researchers indicated that the major deficiency in knowledge is only in regard the impact of pruning on flowering. Thus again technology transfer is of prime importance. Aligns to Key Sub-Strategy 1.

d. Insect management overall ranked down, but at fruit maturity the ranking climbed to be rated next after disease management. This was due to the economic impact of scale and mango seed weevil on the down grading of fruit in the packaging shed or on market access issues. Aligns to Key Sub-Strategy 3.

Table 8. Impact Analysis of RD&E Needs – Priority Ranking

		Grower Assessment		Researcher Assessment		
Practices		**R&D**	**Technology transfer**	**R&D**	**Technology development**	**Technology transfer**
Irrigation		5	5	5	4	5
Nutrition		2	2	3	2	2
Disease Control		1	1	1	1	1
Insect Control		3	4	4	5	4
Canopy Management		3	3	3	3	3
Plant Growth Regulator		5	5	6	6	6
Harvest	Crop Forecasting	3	2			
	Maturity Index	2	2			
	Harvest Aids	1	1			

D. Proposed Investment Plan for next Five Years.

From the survey data, extraction workshops and impact analysis, a major emphasis for AMIA over the next five years needs to be directed towards technology transfer. The survey and workshops clearly indicate that there are three tiers of grower competency across the industry.

The three tiers are:

1. Growers with advanced production and management skills, drawing on a wide range of knowledge sources, utilising consultants where necessary and willing to evaluate new technology. These may be individual growers or corporate enterprises. Active information seekers.
2. Growers with average production skills but below par management capacity. They are generally slower in picking up new technology and rely more on the local reseller or neighbour for the information. Generally come to field days but not training workshop. Do not actively seek new information
3. Growers with well below the average production skills and limited management capacity. Relies heavily on sales representatives (of all qualities). Does not attend information days. Resistant to new ideas.

The challenge for this plan is to develop technology transfer systems that provide the opportunity for all growers to benefit from the AMIA investment. Therefore a range of programs that address one or more of the six sub-strategies are proposed.

The proposed programs are;

Technology Transfer. It is evident that there has been significant research and extension material developed over the past 20 years that is not accessible to the whole industry. A first priority is that this information needs to be packaged in an easy accessible format and made

available to industry and research and information providers. A web based data base that can house all past research and extension material, and also have the capacity to be updated with new data as it becomes available, would be desirable. This activity should commence before any other program.

Outcomes:

- Growers and researchers being better informed about past and current research findings.
- Better communication between and within industry and research providers about research issues.

Estimated cost <$90,000 for 12 months.
Aligns with all six sub-strategies.

Benchmarking production. Grower's appreciation of their costs of production and benchmarking their management standards against industry standards are not happening due to various factors. Benchmarking activities in the Macadamia industry have delivered significant benefits. With the aid of the computer program, Macman, individuals and the industry as a whole, have been able to improve productivity and profitability at both a business and industry level.

Mango growers have identified the need for a computer based farm diary recording system which would enable them to record their management practises and produce the wide range of documents now required by the various food safety, quarantine and quality management systems. This project could start with the development of a computer based farm diary recording system and develop into a benchmarking system similar to the Macman program.

These activities would address Key Sub-strategies 1, 4 & 6.

Unlocking Research. Unlocking research is a proven technology transfer and industry development program to improve the production and market supply system. It is currently being successfully implemented in the Lychee industry and provides a mix of workshops, field days, developmental research and benchmarking through both group and individual processes, with a strong industry communication focus that accommodates the range of grower skills in the industry. It also addresses concerns about the adoption and use of new technologies in an industry that is regionally diverse and reliant on very different environmental and production systems.

The project uses grower based panels in regional areas to test and adapt technologies to customise and improve production and supply chain systems. Campbell and Diczbalis (2001) demonstrated that this is an effective methodology to improve technology adaptation, testing and potential and adoption. The project should target the adoption of research and improved management techniques in the following areas;

o Canopy and flower management.	Key Sub-Strategy 1
o Nutrition and irrigation management	Key Sub-Strategy 1
o Insect pest management	Key Sub-Strategy 2
o Disease management	Key Sub-Strategy 3
o Pesticide application technology.	Key Sub-Strategy 2 & 3
o Harvest quality, sun burn	Key Sub-Strategy 1 & 4
o Training and skills development	
o Delivery of training course via the Internet	

In each target area recommendations will arise for future RD&E, evaluation of field testing outcomes and associated supply chain problems. A feature of this work will be close liaison between the research providers and industry and a high level of industry communication.

The estimated costing for this type of activity is difficult as it will rely heavily on the in-kind allocation by the research providers. The project in Lychee, which covers all growers in Queensland and northern NSW, has a HAL contribution of $110,000 per year, but $210,000 of QDPI&F funding support. This project needs to be nationally coordinated to ensure consistency of information, efficiencies in production of extension material, and sharing of outcomes between regions, but regionally delivered to maximise interaction and uptake of knowledge. The project also needs to address the various tiers of grower knowledge across the industry. This could initially run for about five years then be reviewed, but is a high priority activity.

Outcomes:

- Growers and researchers being better informed about past and current research findings.
- Greater return on AMIA investment in RD&E through increased adoption of research findings.
- RD&E project that align closer to regional and national demands.
- Better communication between and within industry and research providers about research issues.

An estimated cost would be around $150,000 per year and may require additional funding from programs such as the Tropical Fruits Partnerships Program from DAFF.

Disease management. This has been highlighted as a major priority across all regions. A review of disease research in mango has been completed by Dr Chrys Akem in FR02050 and will form a basis for the future research direction. Considerable research work is currently being conducted in two ACIAR projects that have direct benefit back to Australia. It is important that the results from this work are translated back into field practices for Australian mango growers as well as developing specific strategies for the industry. Key areas of research and development as well as approximate costs are;

Activity	2006/2007	2007/2008	2008/2009	Total
1. Inoculum reduction trials	$32,500	$26,000	$20,000	$75,500
2. Anti-fungal evaluations and new product screenings	$22,000	$20,500	$25,655	$68,155
3. Fungicide Resistance management strategies development	$15,152	$17,158	$20,000	$51,310
4. Collaborative Linkages and import of technologies from Overseas institutions.	$10,500	$9,500	$10,000	$30,000
5. Technology Transfer	$9,000	$12,000	$16,000	$37,000
Total	$86,152	$85,158	$90,659	$261965

Outcomes:

- Reduction in volumes of fruit lost to post harvest disease
- Greater confidence in the shelf life of mangoes by retailers and consumers
- Increased opportunities for export fruit
- Greater efficiency in fungicide usage
- Increased economic returns.
- Enhanced sustainable production system

This program align predominately with sub strategy 3, but also 1 (fruit retention) and 6 (reduction in reject fruit and in the longer term, no post harvest treatments).

Insect pest management.

- Finalising sections of the insect IPM work of FR02050, mainly finalising the introduction of mango scale parasitoids. Estimated cost, <$30,000. Further evaluation of pest management strategies need to be progressed, but this maybe delayed until further findings from the two ACIAR projects are completed. Estimated Cost, Uncertain at this stage.

- Extending the outcomes/knowledge from the AusAid (PSLP) and ACIAR projects on mango seed weevil, with a major focus on developing market access protocols. Treatment strategies such as the evaluation and registration of insecticides for mango seed weevil, commercialisation of any potential pheromones will also need to be considered. Estimated cost, $40,000 with Chemical company assistance. Now that MSW has become an impediment to market access for China and some other markets, higher priority may need to be given to this work area.

- Due to the potential loss of dimethoate and fenthion, field management strategies for fruit fly need to be considered as a high priority. Initial work on off crop baiting showed that this has good potential as a field management strategy and, if combined with area wide management strategies to reduce pest pressure, could be developed into a pre-harvest system for possible interstate access through an ICA. A number of similar projects are currently with HAL for other cropping systems eg stone fruit, strawberry and capsicum. Evaluation of the outcomes of this work will assist AMIA in determining the future opportunities for fruit fly management.

Outcomes:
- Maintenance of domestic markets
- Increased opportunities for export fruit
- Greater efficiency in insecticide usage
- Increased economic returns.
- Enhanced sustainable production system

Aligns to sub-strategy 2 but also 6 (reduction in reject fruit and in the longer term, no post harvest treatments).

Nutrition/disease complex. Continue the research into identifying the critical nutrient levels that impact on the plant disease defence mechanisms. Decision on the detail of a future work will depend on the final outcome of this project.

Outcomes:
- Improved nutritional management of mango
- Improved disease management

Aligns with sub-strategies 1 & 3.

Fruit Maturity Index. The survey indicated that about 91% of growers used internal flesh colour to determine when to harvest, with 36% additionally using blush and then another 30% using dry matter as well. However from the workshops a specific need was identified to develop a quantitative measure of fruit maturity at harvest that relates to the consumers' expectation of fruit flavour and shelf life.
Outcome:

- Greater confidence by the consumer in the consistent eating quality of mango.

Aligns to sub-strategy 5.

Crop Forecasting. The crop forecasting system that has been developed in Northern Territory should have the data set broadened to evaluate the potential across all the industry. Not all districts in the initial test need to be included, only the extremes of the production window such as Mareeba and Bundaberg. It is important that both the crop forecasting and fruit maturity index project be considered together because both potentially rely on the accumulation of heat units. Aligns to sub-strategies 5 &6.

Harvesting and Pack shed efficiency options. A review of harvesting and pack shed operations by qualified agricultural engineers to identify areas of operational efficiency and work place health and safety improvements. A similar project has been conducted in banana, utilising 4th year students to conduct time motion studies of workers and machinery in a range of packaging sheds. This review provided some general principals for growers to consider in designing packing lines, and new shed designs. In mangoes this could identify improvements in harvest aids through to robotics within the packaging sheds. A pre-tender project lead by an engineer may need to be scoped to develop the terms of reference for the broader project.

Outcomes:

- Greater understanding of the opportunities for efficiency gains in the harvesting and packaging operation.
- Better targets projects to achieve labour efficiency and work place health and safety. Aligns to sub-strategy 6 and minor areas of 1.

Minor issues the need support. Weed control strategies in new orchards. This is work that could be contracted to consultants or interested chemical companies.

Long Term Physiology Research Plan. Plant physiologists and horticulturists over the next 12 months need to review the focusing questions within the agronomy/physiology section of Table 7 of this document and development concept papers on how best to answer these long term research issues. The paper should not only consider the type of research projects that would be required, but also the skill capacity needed to resolve the problems, the time frame needed, strategies to conduct the work (eg ACIAR funding for some particular activities, ARC grants for PhD students, linkages to other tree crops, etc). Activity costs within this program should be covered within the agencies. This program would mainly align to sub-strategy 1. This paper should be presented to the AMIA in early 2007.

Appendix I

Review of Mango Production Practises

Introduction: The reason for the survey

This survey is being done to gather information from mango growers to be used as a guide for planning research and extension in mangoes for the Australian Mango Industry Association. This survey is part of the "Analysis of mango production practices and R&D needs" project, currently being funded by the Australian Mango Industry Association, Horticulture Australia and DPI&F. The "Terms of Reference" for the project are;

- Conduct an analysis of current mango production across the major Australian production regions to determine the production practices used, including skill levels of orchard managers and assess the impact of these practices on cost, yield and quality, acknowledging potential environmental issues
- Establish baseline data of current production practices and skill levels accounting for any major variations due to region, farm size or other relevant attributes
- Identify issues of mango production with the greatest potential for improvement in terms of cost, yield and quality
- Develop broad research strategies to address these identified issues
- Develop 'business cases' for the preferred research & development strategies to address these potential issues. The business cases are to include the broad R&D strategy, recommendations for implementation and a benefit cost analysis.

To achieve these tasks, we will be asking questions about your current production practises and how you go about making decisions on these practises. This will allow us to determine what the current status is and be able to measure over time what improvements are being made.

Individual practises will be kept confidential and any report or presentation prepared will only include regional summaries.

You will need to set aside some time to complete this survey. You will need you spray diary, orchard records and some historical information to complete the survey. Feel free to add any comments or further information that you think might be relevant to this survey.

If you need any help answering or clarifying any questions or need more information about the survey, please contact the following people:

Rowland Holmes	W: 07 4783 2355	M: 0438 176 235
Bob Williams	W: 07 40641151	M: 0417 702 439
Terry Campbell	W: 07 4155 6244	M: 0427 602 007
Greg Owens	W: 08 8999 2284	M: 0407 992 267
Julie Bird	W: 08 8973 9738	M: 0409 282 256
Peter Johnson	W: 08 9166 4018	M: 0427 440 211

Grower details

Grower (Optional): .....

Date of Survey: .....

Production region:

☐ Bowen	☐ Bundaberg	☐ Burdekin
☐ Carnarvon	☐ Darwin	☐ Katherine
☐ Kununurra	☐ Mareeba	☐ Northern NSW
☐ Rockhampton	☐ South East Qld	

Question 1. What is the vision for your farm? .....

.....

.....

.....

Question 2. Do you record you farm management practises on a computer?

☐ Yes

☐ No

Question 3. Do you use a computer based Farm diary recording system?

☐ Yes

If Yes, Which one? .....

☐ No

Question 4. Would you use a computer based Farm diary recording system if a suitable one was available?

☐ Yes

☐ No

Question 5. Would you change your farming system to meet certain export protocols? (eg. mango seed weevil, bacterial black spot)

☐ Yes

☐ No

Question 6. How important are the following as sources for information on growing, harvesting and packing mangoes. Please rate each of the information sources as:

A - *Important or often used* ***B*** *- Sometimes used or* ***C*** *- Never used or not important*

Chemical resellers		Pest scouts & consultants	
Other Growers		Market agents or merchants	
People in your Industry Association		Chemical manufacturers / companies	
Local Departmental Officers		DPI&F Call Centre	
Field days or seminars		Internet	
Mango Pests & Disorders Book		Mango Care newsletter	
Mango Agrilink kit		Operation KP (NT)	
Good Fruit & Vegetables		Local Producer Association meetings	
Pests, Disease and Disorders of Mangoes in the Northern Territory			
Other sources (specify):			

Question 7. Below is a list of areas relating to growing, harvesting and packing mangoes. Could you please identify areas in which more information would help you to make better decisions in growing, harvesting and packing mangoes?

A - *Important* ***B*** *- Useful* ***C*** *- not important* ***D -*** *not sure*

Business Management		Canopy Management (pruning)	
Benchmarking (best practise) - costs & returns		Disease control	
Export / Quarantine requirements		Flowering	
Harvesting methods		Integrated pest management	
Irrigation		Latest Research results	
Marketing (prices & throughput's, etc.)		Nutrition	
Overseas Research		Packing shed design	
Postharvest handling		Spray application / calibration	
Varietal information and breeding		Computers & software	
Other topics (specify):			

Question 8. How important do you think the following management practises or aspects are in regard to production and fruit quality?

	Not important									Very important
	1	2	3	4	5	6	7	8	9	10
Good irrigation practice										
Pruning and canopy management										
Good nutrition management										
Insect pest management										
Disease management										

Question 9. What price range did you get for your mangoes in the 2004 mango season?

			Variety or Block			
	Pack type	**Weight (kg)**	**KP**	**R2E2**		
Premium	**Tray**					
1st grade	**Tray**					
1st grade	**Bulk**					
2nd grade	**Tray**					
2nd grade	**Bulk**					

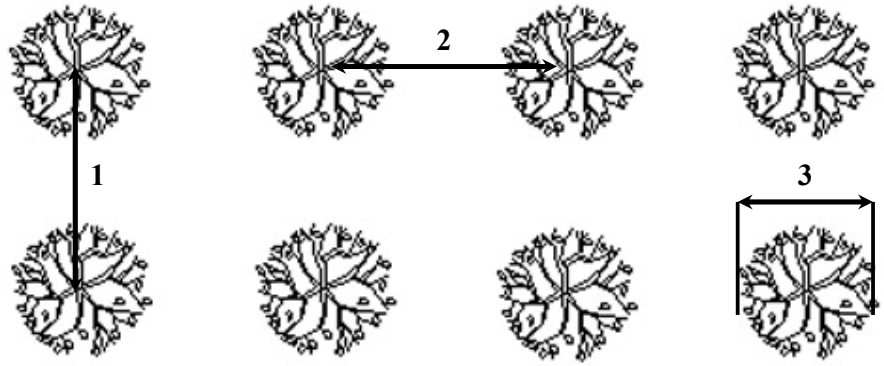
Question 10. How much do you spend per hectare per year (approximately) on the following?

	Young trees	**Mature trees**
Fertiliser		
Disease and pest chemicals		
Growth regulators		
Irrigation		
Pruning		
Slash and mowing		

Orchard Details

Question 11. What is the layout of your orchard? (tree number, variety, tree spacing, tree height etc.)

Paddock Name/No	Variety	No. of trees	Year of planting (Age)	Row spacing (metres) (1)	Trees spacing (metres) (2)	Canopy diameter (metres) (3)	Tree height (metres)	Yield (kg)
Total								



Question 12. What are the production characteristics of your orchard?

Paddock Name/No	Rootstock	Soil type	Irrigation method	Water use (Ml per year)	Windbreaks (Yes or No)	
					Species	Age
Total						

Soil type Sandy, Sandy loam, Loam, Clay loam, Clay: red or black, Mixed

Irrigation type Flood, Micro Sprinkle, Trickle

General Phenology

Question 13. When do the following growth stages or events occur in your orchard for each variety?

Growth stage	KP		R2E2		Keitt							
	Week	Month	Week	Month	Week	Month	Week	Month	Week	Month	Week	Month
First Flower												
Main Flowering												
First fruit harvest												
Number of flushes per year												

Orchard Management practises

Pruning & Canopy Management

Question 14. How and when do you prune you mango trees? Please fill out the following table for up to **three (3) of your main blocks** using the key below the table.

Block	Method of pruning	Week	Month	Cost	Growth Regulator	How long between growth regulator applications?

Method of pruning: M - Mechanical, H - Hand pruning, R – Root pruning, C - Cincturing

Growth Regulator Cutback / Payback, Austar, Sunny, Diesel, other or none

How often Every year, Every second year

Question 15. If you use a growth regulator, how is it applied? .....

Question 16. What do you do with your pruning's? .....

.....

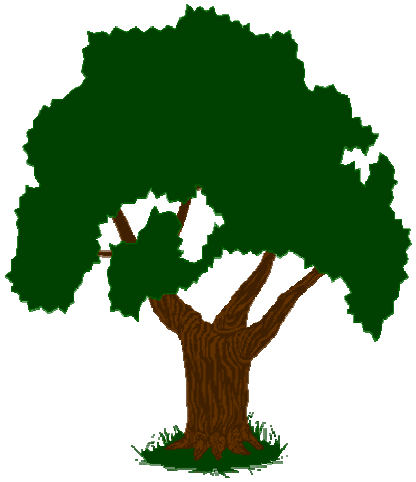
Question 17. Have you seen your mechanical contractor sterilise or clean his machinery before coming onto your property or on departure?

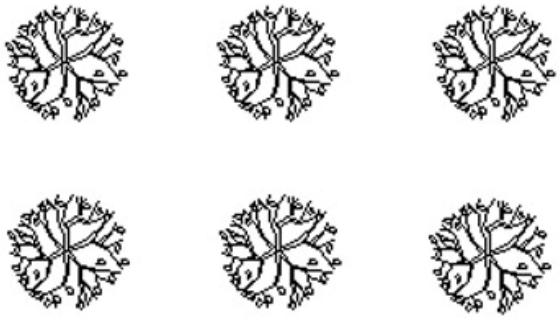
☐ Yes

If Yes, How? .....

☐ No

Question 18. Can you draw lines or arrows on the pictures below to show the pruning cuts you would make and describe how you would prune?





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Question 19. How confident are you about knowing **<u>when</u>** to prune for optimum production and fruit quality?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Question 20. How confident are you about knowing **<u>how</u>** to prune for optimum production and fruit quality?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Irrigation

Question 21. What percentage of your water is applied at the various growth stage of the crop?

Flowering	Fruit set	Fruit Development	Harvest	1st flush

Question 22. What is your source of water?

Regulated	Supplemented stream	☐
	Bore	☐
	On farm dam	☐
	Irrigation scheme	☐
Non Regulated	Stream or river	
	Bore	☐
	On farm dam	☐

Question 23. How much per Mega-litre (ML) does you water cost? $ ..... ML

Question 24. How much fixed costs do you pay per hectare for water? $..... per ha

Question 25. Approximately, how much water do you apply per hectare? ..... ha

Question 26. How much does it cost to pump water for 1 ha of mangoes per year? $ .....

Question 27. How do you know when to irrigate? .....

.....

.....

Question 28. Have you ever used any form of moisture monitoring equipment?

☐ Yes. Go to Question 29

☐ No. Go to Question 32

Question 29. What type of equipment did you use?

☐ Tensiometer

☐ Gofer or similar

☐ Enviroscan or Agrilink

☐ Other

Question 30. Do you still use this moisture monitoring equipment?

☐ Yes. Go to Question 32

☐ No. Go to Question 31

Question 31. Why did you stop using this equipment?

- ☐ Too difficult to use
- ☐ Ineffective
- ☐ Too costly to have consultants explain results
- ☐ Now know how to read an indicator of soil moisture without the equipment
- ☐ Other reason ……..

Question 32. How confident are you in making the correct decision about **when** to irrigate and **how much** water to apply?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Nutrition

Question 33. How do you decide on what and when to fertilise? .....

.....

.....

Question 34. Do you routinely use a soil analysis?

☐ Yes

☐ No

Question 35. Do you routinely use a leaf analysis?

☐ Yes

☐ No

Question 36. How confident are you in the recommendation made from these analysis?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Question 37. Are you able to interpret the soil/leaf analysis yourself?

☐ Yes

☐ No

Question 38. How confident are you that you are applying the correct amount of nutrients for optimum production?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Pest & Disease Management

Question 39. Below is a list of insects and diseases. Can you rank them in order of importance and incidence for your orchard?

1. Major 2. Moderate 3. Minor 4. Not sure 5. Doesn't occur or haven't seen

Mango Insect pests

☐	Mango scale	☐	Mango planthopper
☐	Flower feeding caterpillars	☐	Mango shoot caterpillar
☐	Tip borers	☐	Fruit fly
☐	Mango seed weevil	☐	Swarming leaf beetle
☐	Thrips	☐	Mites
☐	Mango leafhopper	☐	Mango leafminer
☐	Fruit spotting bug	☐	Termites
☐	Others		

Mango Diseases & Disorders

☐	Anthracnose	☐	Bacterial black spot
☐	Powdery mildew	☐	Mango Scab
☐	Stem end rot	☐	Botrytis flower blight
☐	Dendritic spot	☐	Sunburn
☐	Decline or dieback	☐	Internal disorders
☐	Others		

Question 40. How frequently do you use the following to decide when to spray?
(always = 3, often = 2, sometimes = 1, not used = 0)

- ☐ Regular monitoring (personal)
- ☐ Pest scout or consultant
- ☐ Neighbours
- ☐ Chemical resellers
- ☐ Crop cycle (eg. flowering, fruit set, flush)
- ☐ Calendar (Every 10 days or 2 weeks or "It's two weeks since my last spray")
- ☐ other [specify type] .....

Question 41. Classify the following pesticides used for controlling pests and disease in mangoes?

Chemical	Broad Spectrum	Targeted	Soft	Protectant	Curative	Systemic
Applaud						
Amistar						
Carbaryl						
Chlorpyrifos						
Copper						
Dimethoate						
Endosulfan						
Mancozeb						
Octave						
Roundup						
Sprayseed						
Supracide						

Spray application

Question 42. What type of sprayer do you use? (tick)

- ☐ airblast
- ☐ mister
- ☐ other ……

Question 43. When did you last calibrate your sprayer?

- ☐ every time it is used
- ☐ in the last 12 months
- ☐ 12 months to 3 years
- ☐ > 3 years

Question 44. When did you last replace your nozzles?

- ☐ in the last 12 months
- ☐ 12 months to 3 years
- ☐ > 3 years
- ☐ never

Question 45. What spray volume do you use per tree? ..... Litres

Question 46. What is the pH of your water normally? .....

Herbicide sprayer

Question 47. What is the swath width of your herbicide boom? ……. metres

Question 48. What is your herbicide spray volume per hectare? ..... litres/ha

Integrated Pest Management

Question 49. What does the term integrated pest management or IPM mean to you?

.....

.....

.....

Question 50. Do you believe you use IPM on your farm? If yes, in what way?

.....

.....

.....

Attitudes to pest and disease control

Question 51. How confident are you of being able to correctly identify the main insects in mango?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Question 52. How confident are you of being able to correctly identify the main diseases in mango?

0	1	2	3	4	5	6	7	8	9	10

Not confident Very confident

Question 53. How useful do you think beneficial insects (parasites, predators) would be in keeping insect pests from causing more damage?

0	1	2	3	4	5	6	7	8	9	10

Not useful Very useful

Question 54. How useful do you think biological control agents would be in keeping diseases from causing damage?

0	1	2	3	4	5	6	7	8	9	10

Not useful Very useful

Harvesting: Field operations

Question 55. How do you decide when fruit is ready to harvest? (eg, Blush, Flesh colour, Dry matter, Market price etc)

.....

.....

.....

Question 56. Do you have contract picker?

☐ Yes

If Yes, what rate do they charge? .....

☐ No

Question 57. Do you employ your pickers on a:

☐ Contract basis or $ ..... per ..... bin

☐ Contract basis or $ ..... per ..... kg

☐ Hourly basis $ ..... per hour

Question 58. Do you have a bonus system?

☐ Yes

If Yes, please explain .....

.....

☐ No

Question 59. How do you harvest?

☐ Destemmed in the field (eg. Harvest Aid etc.). Go to Question 60

☐ Stem attached and destemmed in the packing shed: Go to Question 67

Destemmed in the field (Harvest aid)

Question 60. How many harvest machines do you have? .....

Question 61. How many people are working on the harvest machine? ……

Question 62. How many people are involved in the non picking part of harvest? .....

Question 63. Can you give an estimate of the time to harvest 1000 trees of KP, R2E2 or another variety at the following average yields?

Tree Yield	KP	R2E2	Other
30 trays			
25 trays			
20 trays			
15 trays			
10 trays			
5 trays			

Question 64. How does the fruit get from the unit to the shed

- ☐ Bulk bins (300 kg)
- ☐ Bulk bins (500 kg)
- ☐ Fruit crates
- ☐ Other .....

Question 65. How is the fruit transported to the packing shed? .....

Question 66. How many kg on average gets harvested per day (total farm)?.....

Stems attached & destemmed in the Packing shed

Question 67. How does the fruit get from the field to the shed?

☐ Fruit crates

☐ Other .....

Question 68. How many pickers do you have in the field? …… per day

Question 69. How many people are involved in the non picking part of harvest? .....

Question 70. Can you give an estimate of the time to harvest 1000 trees of KP, R2E2 or another variety at the following average yields?

Tree Yield	KP	R2E2	Other
30 trays			
25 trays			
20 trays			
15 trays			
10 trays			
5 trays			

Question 71. How many kg on average gets harvested per day (total farm)?.....

Picking yield

Question 72. Give an estimate of the percentage of fruit left in the paddock in a good year? ..... %

Question 73. Give an estimate of the percentage of fruit left in the paddock in average year? ..... %

Question 74. Give an estimate of the percentage of fruit left in the paddock in a bad year? ..... %

Question 75. What are the main reasons for leaving fruit in the paddock?

Good: .....

Average: .....

Bad: .....

Packing shed

Question 76. Do you pack your own fruit?

☐ Yes. Go to Question 78

☐ No

If No, How much does your packing cost you per tray? $ .....

Question 77. What does this include? (carton, tray liner, cooling, freight, selling costs etc.)

.....

.....

..... Go to Question 88

Question 78. Approximately, how many staff are involved in the following areas of your packaging shed?

Bin Tippers/Desappers .....

Grading .....

Packing & Stickering .....

Palletising & cooling .....

Other (Consigning, QA etc.) .....

Question 79. What training procedures do you have for you workers in your packing shed?

.....

.....

.....

Question 80. Do you use a hot dip to control diseases?

☐ Yes

If Yes, what chemical do you use? .....

☐ No

Question 81. Do you use Sportak to control diseases?

☐ Yes

☐ No. Go to Question 83

Question 82. If yes, how is the chemical applied?

☐ Non-recirculated spray

☐ Recirculated spray

☐ Dip

Question 83. Do you use an insecticide treatment?

☐ Yes

If Yes, what chemical do you use? .....

☐ No. Go to Question 86

Question 84. How is the insecticide applied?

☐ Non-recirculated spray

☐ Recirculated spray

☐ Dip

Question 85. Are the Insecticide and Sportak mixed in the same spray tank?

☐ Yes

☐ No

Other issues

Question 86. How or where do you dispose of the following?

1. Hot dips ..... (Spin flo, Benlate)
.....

2. Cold fungicide ..... (Prochloraz/Sportak)
.....

3. Insecticide ..... (dimethoate, fenthion)
.....

4. General waste water .....
.....

Question 87. What system do you use for product traceability?

.....

.....

Question 88. What are the approximate costs involved with employing and managing one person? (tax forms, training, supervisions, accommodation etc.)

.....

.....

.....

Question 89. Who takes care of your labour hire? .....

Question 90. What services do they provide and what is the cost of these services?

.....

.....

.....

Marketing mangoes

Question 91. Total number of Marketable trays of variety and quality

			Variety or Block				
	Pack type	**Weight (kg)**	**KP**	**R2E2**			
Premium	**Tray**						
1st grade	**Tray**						
1st grade	**Bulk**						
2nd grade	**Tray**						
2nd grade	**Bulk**						
Processing							

Question 92. What were the main reasons for fruit being downgraded to processing?

.....

.....

Question 93. Would you like me to send you a copy of the summary results of this survey?

If yes, note mailing or email address: .....

.....

.....

Thankyou for taking the time to help us by completing this survey

Appendix II

RD&E Extraction Workshops

Burdekin Meeting: 9th March 2005

Present:

Industry	**Industry**	**Facilitators**
Fred, Glenda & Justin Dibella	Vince Curro (Sungold)	Rowland Holmes
Peter & Paul Le Feurve	Charlie Tama	Chrys Akem
Dennis & Pat Staples	Sam & Alfie Papalardo	David Hamilton
Alex Johnson	Fiona Mobbs (NAP)	Irene Kernot
		Bob Williams

ESTABLISHING AN ORCHARD:		
Issue	**Key points**	**Confidence**
Variety	• KP try for 2 weeks earlier • Grafted, rootstock	1
Soil type	• Need sandy, light, gravely soil: results in superior fruit quality • Not an issue for processing fruit • More effort managing non-suitable soil types for fruit quality	5
Water quality	• pH, salinity, quantity, reliability, hardness • Water hardness could be interfering on tree growth or impacting on fruit quality	5
Planting spacing	• 12x8, 10x8 (100-120 trees/ha), 9x8 • To get decent yields need wider spacing's • Prune both ways to maximise surface area per hectare • This will increase the yield of blushed fruit	4
Direction	• East-west • Good to be able to harvest one side then couple weeks later the other.	1-2
Shaping/Pruning	• Important to structure tree when young • Excessive pruning can reduce production • For spraying and later structure • Tree architecture means more leaves, better photosynthesis and more energy	4
Irrigation	• Sprinklers, that are adaptable as the trees grow • Minimum cost system • Water the whole block in a day • Fertigation	5
Nutrition	• Current recommendations are OK	5
Windbreaks	• To minimise blemish & marks due to wind & dust • Not thought of 20 years ago. • Need to identify best species for wind and beneficial insects, not hosts for pests	Value: 1 Type: 2
Soil drainage	• Laser levelled, not mounded (problems with using harvest aids)	5
General Comments	• Establishment of orchards not a real issue	4

HARVEST TO HARVEST				
Issues	**Key Points**	**K**	**C**	**I**
Pruning	• Crucial to do early • Need to get flush on outside of the tree • Prune for tree size and yield • Late pruning can effect flowering • Internal pruning and sucker control critical, but can be done later. • Pruning for disease control, but yet to see the results. • Need more information of tip pruning using Ethrel • Excessive pruning can increase trunk sunburn			
Growth regulators	• Uncertain about the long term effect, build-up in the plant or loss of efficacy. • Part of the system of controlling tree size • Cultar treated trees, fruit matures earlier (about 1 week). • Effects on fruit quality are unknown. • Climate has a major impact on the efficacy. • Information presented in Mango Care on usage and tree size and health.	2 4	2 4	3 3

Nutrition	• Immediately after harvest to trigger flushing
	• Need rain also to trigger flushing
	• Confident about rates and timings, but still have concerns about:
	  o Rates of N on fruit drop
	  o Trace elements
	  o Gypsum/Potassium
	• Need easy methods to measure plant carbohydrate levels in relation to tree phenology
	• Nutrition programs are grower secrets
		
		4
		2
			
			3
			2
				
				5
				4

Irrigation	• Fertigation	4	4	4
Disease	• Need to understand the disease threshold levels to reduce fungicide applications • Disease forecasting • Inoculum reduction – best methods • Impact of fungicides on flower pollinators • Need to reduce dependence on Fungicides • Alternatives to fungicides	2	2	5
Insect pests	• Scale • Need to control caterpillar level on early flushes • Need to reduce dependence on insecticides • IPM systems	2	2	5
Critical issues	• **Foliage development** • **Flower development** • **Fruit set** • **Fruit retention** • **Need to identify the critical issues impacting on these four stage of plant growth**			

HARVEST				
Issues	**Key Points**			

Labour	• Staff intelligence
	• Finding, recruiting, training, retaining them
	• Want to minimise the number of staff needed and maximise the efficiency of what we have
	• Need people who know each other to work as a crew on a harvest aid
	  o They need to be come as a team to work efficiently
	  o Would rather employ teams of pickers than individuals
	  o Problem: 1 person drives himself to work. In a team, only 1 has a license or car so if he can't make it, no one can
	• Backpackers organisations need more guidance
	  o Need to talk to Backpacker organisations about coordinating things more
	  o Provide better information on starting times
	  o Need for Crop forecasting system (timing, amount etc.)
	• Myers Briggs for team analysis
	• Need a method to estimated yield to determine the volume of labour needed. Linked to crop forecasting system			

Time to Harvest	• Depend on what is the targeted market.			
Harvest Aids	• Easier on the workers, less numbers of staff • Do they increase the damage to the fruit • No need for desappers • Reduce sap burn • Cherry picker style: Picks more per person than a harvest aid machine with a picking crew (average per person on the crew) • People are working as individuals rather than part of a team • Impressed with Cherry pickers because they don't drop as much fruit **Cherry Picker Harvest aids: Positives** • All of the fruit is hand picked • Harvest more fruit per tree • More economical • Double the productivity of a person • Know exactly who is picking what • Pickers are closer to the fruit to estimate fruit maturity • Top of the trees mature first so can pick this fruit at the optimum time • Can spot pick earlier with smaller teams **Cherry Picker Harvest aids: Negatives** • Higher maintenance, high capital cost • Water replenishment • Training and skill level is much high for people to drive a Cherry picker • Need to keep the extended height below 3m to reduce the WHS issues you are dealing with (still get an extra 2m reach with a person) • If you want 20 pickers, you need to interview 100, trial 60 • More tree damage and irrigation lines			

PACKING SHED				
Issues	**Key Points**			

Hot Dips	• Why spend money heating fruit up, and then have to cool down. Get rid of post harvest treatments
	• Does heating (hot dip) impact on shelf life (ripening & disease) in relation to long-term storage
	  ○ Does heat negatively impact?
	  ○ What effect does a hot dip have on fruit shelf life (physiologically)			

Computerised Grading and labelling	• Increases efficiency in the shed and office. • Traceability • Maintenance & service of equipment is a problem.			
Other issues	• Try and get rid of individual fruit stickers • Box design needs to be improved – strength			
General issues	• Need to have a true cost of production to demonstrate to the banks the difficulties of mango growing			

Kununurra/Katherine meeting, 14th March 2005

Present:

Industry	**Industry**	**Facilitators**
Lincoln Heading (Kununurra)	Pat Buchanan: (Kununurra)	Julie Bird
Diane Robinson: (Kununurra)	David Quin: (Katherine)	Peter Johnson
Craig Dobson: (Kununurra)	David Higgins (Katherine)	David Hamilton
John Denbow (Kununurra)		Francis Bright
		Bob Williams

ESTABLISHING AN ORCHARD				
Issue	**Key points**	**Knowledge**	**Confidence**	**Impact**
Variety	• There is variation in the KP in Kununurra. Some consistently perform better than others. • Grafted plant are more consistent than seedling • Need to have a spread of varieties, so that harvest is spread out over a period of time. • Consumers determine what variety. • There is sufficient information available on varieties			
Rootstocks	• Generally very good appreciation that rootstocks are beneficial and would be prepared to pay a higher price for plants if the rootstock was superior. • Top working in Kununurra not very successful • Desirable to have a rootstock that suppresses growth, greater ability to absorb nutrients and readily increase carbohydrates.			
Orchard orientation	• East/West. Adjusted by region for the path of the sun around harvest time. • This is to minimise Sunburn • This is knowledge from experience and not from research in mango • *Developmental work to confirm the optimum orchard design. Have somebody like Simon Middleton talk about*			
Spacing	• 7 x 4.5 or 7 x 5 for Kununurra • With hedge rows at this spacing pick 95% of fruit from ground. • 10 x 5 in Katherine • Heat units are greater in Katherine • Alternative is smaller growers with large trees on 9 x 8 – tall and pick with a cherry picker. High yield per tree.			

Irrigation	• All would prefer mini sprinkler, but many orchards have been established with flood. • Irrigation must provide water into the row spacing to encourage grass cover (Jarra grass in Katherine). BW suggested the possibility of Rhodes grass for easier establishment. • Grass is linked to soil health and development of beneficial insects. (not sure what the beneficial's actually are) • Water pH is a major problem. High in Ca 7.0 to 8.5 pH in both Kununurra and Katherine. • Causes problems with foliar sprays and many use rain water specific for this. • Ca causes blockage in irrigation pipes and sprinklers • High pH reduces the availability of some nutrients. • New establishments utilise irrigation monitoring devices and feel that they have a good understand of their operation. • Good service. • Correlate data with crop factor and pan evaporation. • Do not know what is happening in the plant. I.e. correlation between monitoring equipment and what the plant actually needs. This is important. Need gadget to easily measure water flow in the plant.			
Herbicide	• Soil pH causes problems with pre-emergent herbicides i.e. Surfan/simazine have been used, but not happy with the control. Use glyphosate and Sprayseed. Sometime include Goal. • In the new large plantations, generally have to spray every 6 to 8 weeks			
Tree Architecture	• Need to get the height of first branching right. • Aim for 3 to 5 branches to increase fruiting points. • Aim for about 1m above the ground. • PJ has demonstrated high density is possible • Trunk sunburn in young plants is an issue. Trunks are painted with white wash or white plastic paint. Sometimes include copper fungicide to reduce fungal infection. (PJ knows the name of the fungus). • Document case study for a range of systems and look at possibilities. (Information maybe out there). • Not sure when to start to tip prune			
Nutrition	• Generally plenty of information is available to get by, but not very confident in the reliability of the data. • In regard to the current service providers (Crop tech, Incitec etc), would like to have regional specific recommendations. Not based on Bundaberg data. • Many Katherine growers are moving to biological fertilisers, but have limited confidence in them			
Disease management	• Need to start managing disease early in the plants growth.			

	HARVEST TO HARVEST			
Labour	• Supervisors best ratio of 1:5 minimum • Accommodation • Access • Immigration (region specific) • Allergy to mango sap • WHS/Induction • Transport is organised Kununurra and Katherine			
Disease	• SER • Alternaria • Anthracnose • Disorder – X. The WA department has a molecular biologist look at the symptoms as well as Peter Hofman • Disease management is critical in regard to export • In high density planting disease management maybe more critical	Kununurra 2 Katherine 1	1 1	
Insect Pest	• Monitoring and economic threshold levels are unknown. • Insects o Red shoulder leaf eating beetle (Monolepta), o Jassids/flattids o Etc o Fruit fly o Winged vertebrates • Loss of dimethoate			
Sunburn	• 20 to 30% unsaleable fruit on most trees (both in Kununurra and Katherine. • Surround/Allie etc, mixed options on how successful, some OK other have a problem • All varieties effected. • Is the ability of the plant to supply sufficient water on the sunny side the issue?			
Water	• Have Ag notes on water usage, but stress at the end of foliar development. • In regard to the phenology cycle there is a lot of unknowns when to stress and not to stress and the impact these decisions have on yield and quality.			D&E R&D
Growth regulators	• Cost of Paclobutrazol • What is the correct timing – End of 1st Flush? • Temperature is very hot when application is necessary and plants have stop photosynthesis (vapour pressure deficits), therefore limited success. • Application methods, in regard to root development. I.e. phenology cycle of Whiley is based on subtropical mangoes. • Need to redo the phenology work (some of this work may have been done by CSIRO, need to check) • What is the accumulation effect of paclobutrazol			

Pruning	• Timing, when the contractor is available • How often?, all of the tree every year or not • What are the benefits of tip pruning, root pruning (if and when), Chemical options • What are the best systems to use to set up the trees to minimise labour • Flush in May not desirable, information on burning off with Ethrel • Pruning in relation to carbohydrates • Readily available vapour pressure deficits during these times, to indicate that the plant is functioning. Need easy systems for measuring this (gadget). • How much canopy is necessary for light interception. What leaves are functioning and when. (CSIRO data verses PJ data). • Disease management through pruning is critical.	3.5	2	
Fertiliser/ Soils	• Regionally based recommendations. • High pH soils. • Soil Health may improve conditions	2	1.5	
Pollinators	• What are the pollinators?? What are the key pollinators and when do they work. • Viability of pollen (work from the breeding program has indicated that pollen is only viable in the tropics for a very short time (2 hours). This may have a significant impact on productivity. • Number of male vs. female flowers. • What is the impact of temperature on the M/F ratio. • What is the impact of nutrition on pollen viability • This problem appears to be specific to KP. • Eg 100% terminals, 75% flower initiation, 50% pollination/fertilisation, 25% fruit set, 5% fruit retention. To improve productivity, some of these steps need to be improved.			

HARVEST				

Time to Harvest	• Indicators
	  ○ Internal colour
	  ○ Heat units
	  ○ Hand feel (fullness of fruit)
	  ○ Dry matter
	  ○ Milk/sugar spotting
	• Need to have a quantitative/objective measure, so that there is a correlation between the field and end user (wholesaler).
	  ○ Long term objective fro a quantitative measure
	  ○ Short term objective, empowering growers and wholesalers in communication. Change management
	• Assess the possibility of specific gravity (density) and a method of sorting out immature fruit in the packaging shed. (refer to some work that Yan started).
		2	1	

Harvest	• Need to quantity the benefit of leaving stem/button on mango for SER control/reduction/delay onset, compared to removing stem • With short cut stems, fruit can go through the graders.			

Darwin Meeting, 17th March 2005

Present:

Industry	**Industry**	**Facilitators**
Phil Vivian	Wayne Roscarel	David Hamilton
Ian Baker	Rebecca Mahony	Chris Wicks
Terry Sullivan		Bob Williams

ESTABLISHING AN ORCHARD				
Issues	**Key Points**	**Knowledge**	**Confidence**	**Impact**
Location	Production window		4	5
	• Climate		4	5
	• Soil type	3	4	5
	• Soil structure			
	○ Uniformity	3	4	5
	○ Manage the site to suit soil. General information is available but not specific.			
	• Water availability and quality		2	4
	○ Impacting on nutrition			
	• Access, impacting in infrastructure			
	• Environment	3.5	2	5
	○ Urban encroachment			
	○ Heritage			
Variety	Productivity/pack-out/Targeted consumer/disease	2		5
	• Size,			
	• 35 to 45 days shelf life			
	• Technical support for each new variety eg like B74. agronomic and post harvest			
Root stocks	Reduced precocity	2	2	5
	• Disease control			
	• Increase uptake of nutrients			
	• Uniformity of flowering			
	• Reduced biennial bearing.			
Orchard design	Spacing	3	3	3
	• Labour efficiency			
	• Orientation north/south or east/west	3	3	5
	• High density vs. low density – locality specific eg			
	○ Low density plantings – warmer areas			
	○ High density plantings – cooler areas	3	3	4

Pre plant	Pre-emergent herbicides	3	4	3
Irrigation	Sprinkler/Drip – Wettable area determined by; o Row orientation o Sprinkler placement • Impacts on sunburn – what is the impact of humidity • Location may determine the type of irrigation that is needed. • What is the water requirement for appropriate tree development. • No rural water use efficiency project in NT • Monitoring equipment – confident information is available. • Relationship between water in soil and water in plant; o Inconsistent results between CSIRO and DBRID (Yan) o This has a big impact on the design of the irrigation system • Baseline data on; o Heat/leaf wetness/climate ▪ What are the events that trigger responses in the plant?	2	2	5
Nutrition	• When the plant is young - easy	2	2	5
Pruning	• What canopy do we want at the end, which is best? o *This could be a survey as there is a lot of grower information available that could provide the answer.* • Canopy to fruit ratio is not known in mango. In kiwi fruit it is know that at pruning time 6 leaves are necessary. Ian Bally has done some research on Keitt that indicates that the greater the fruit to leaf ratio the better the fruit quality. This type of information is needed for Mango. Suggest a survey first of specific pruning practices. • Structure – what is best for the type of marketing system? • Timing of hedging, in relation to the plant phenology	1	2	4
Windbreaks	• Limited knowledge for mango o Does it reduce wind rob? o Does it reduce water loss? o Does it increase fruit quality? • What are the best o Species? o Planting density? o What is the impact on beneficial - -ve or +ve? • *There maybe generic data available for other crops that could be extrapolated. Have discussion paper developed, then possibility do developmental work*	2	1	3.5

<table>
<tr><th colspan="5">HARVEST TO HARVEST</th></tr>
<tr><th>Issues</th><th>Target is to have flowering in May (Darwin)</th><th>Knowledge</th><th>Confidence</th><th>Impact</th></tr>
<tr><td>Flush</td><td>• How many is necessary?
• Biennial bearing – flushing as quick as possible</td><td></td><td></td><td></td></tr>
<tr><td></td><td>• How do you turn a flush on?
• How do you turn a flush off?
• Flowering is a function of
o Flush age & temperature (knowledge is not complete, need more information)
o Flush age >30 days – leaf maturity
• In NT, have to be careful not to cause flushing too early, because it is then difficult to stop.

Need to be able to manipulate flowering via pruning so that flowering & harvest be regulated. Target eg sequential flowering.

<table><tr><td colspan="5">Block Number</td></tr><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td>1st flowering & harvest</td><td>2nd flowering & harvest</td><td>3rd flowering & harvest</td><td>4th flowering & harvest</td><td>5th flowering & harvest</td></tr></table>
• What are the critical factors in the fruit/plant that is giving high fruit quality</td><td>1</td><td>1</td><td>5</td></tr>
<tr><td>Nutrition</td><td>• Considered to biggest impact on Productivity & Fruit quality.
• Nitrogen, potassium, and calcium.
o Timing
o Quality
o Total amounts in the soil
o Availability to the plant
• N:P:K ratio’s for mangoes ?? Generic data available only
• TE eg B and Zn plus others.
• Growers are playing with nutrition but there are big gaps
• All information in Ag notes is not good.

Process:
• Compile data
• Validate with grower and research review
• Grower demonstration research monitoring</td><td>3</td><td>1</td><td>5</td></tr>
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<table>
<tr>
<td>Interactions</td>
<td>
<table>
<tr><th></th><th>PGR</th><th>X</th><th>Y</th><th>Z</th></tr>
<tr><td>Pruning</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nutrition</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Irrigation</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Climate</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>
X,Y, & Z are new tools that need to be developed that can be used that will enhance the control over flushing and ensure uniform flowering.
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<td></td><td></td><td></td>
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<tr>
<td>Pollination</td>
<td>
<table>
<tr><th></th><th>Terminal development</th><th>Flower development</th><th>Fruit set</th><th>Fruit retention</th><th>Accumulated fruit number</th></tr>
<tr><td>Optimum</td><td>100</td><td>90</td><td>100</td><td>80</td><td>72</td></tr>
<tr><td>Actual B74</td><td>80</td><td>70</td><td>150</td><td>70</td><td>52</td></tr>
<tr><td>Actual KP</td><td>80</td><td>30</td><td>60</td><td>30</td><td>4.2</td></tr>
</table>

Male female ratio
Pollen viability
Impact of heat
Pollen vectors

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</tr>
<tr>
<td>Pests & disease</td>
<td>

What is the EIL of insect damage on the flush
Impacts of seed weevil at flushing time are unknown.

</td>
<td>2</td><td>3</td><td>3
5</td>
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Up to Flowering and onwards

What should be done to reduce disease inoculation levels
What diseases effect fruit set

Do not have IPM and IDM systems or the tools to achieve
Chemicals in mango not working the best
IDM needed

Fungicide resistance
Alternative pre/post harvest fungicides not good (except for Amistar.
Need alternatives to diathane/copper
Monitoring protocol

SER not a high problem in Darwin
Need major focus on application equipment, particularly at low volumes.

<table>
<tr><th>Growth Stage</th><th>Number applications</th><th>Fungicide</th></tr>
<tr><td>Foliage develop</td><td>2</td><td>Copper/diathane</td></tr>
<tr><td>Flower</td><td>2 – 4. 10 days apart</td><td>Diathane/Copper. Octave if wet</td></tr>
<tr><td>Fruit</td><td>10 to 21 day intervals
5 – 10 applications</td><td>Diathane/Copper</td></tr>
<tr><td></td><td>1</td><td>Amistar</td></tr>
</table>
</td>
<td>1

1</td><td>2

2</td><td>5

5</td>
</tr>
</table>

HARVEST				
Issue				

Timing	• Key criteria
	  ○ Heat sums – particularly for planning
	  ○ Dry matter (not applicable for all varieties)
	  ○ Flesh colour
	  ○ Specific gravity (been around for a while with little confidence)
	• Would like to have a rapid quantitative non-destructive test that could be a industry standard.
	• NIR/colorimetry would reduce the % class variations in a box. I.e. reduce the incidence of 1 class 2 fruit in a class 1 box or a class 1 fruit on a class 2 box.
	• Variation of fruit maturity on a tree and within a block
	  ○ Aim for 1 pick/block
	  ○ Allows for greater % of fruit out of grade eg.
	Labour efficiencies.
	100% of fruit harvested in 1 pass 80% in grade,
	or
	30% of fruit harvest in 3 passes 30% in grade, 5% in grade
	Solutions:
	• Better knowledge on fruit/leaf ratios
	• New tools for regulation of flush & flowers development.
			1	1	5

Processing	Mechanical Harvesting			
Harvesting	• All off the ground • For other systems the pack-out ratio's are very poor			

Sap	• 20 – 30% of class 2 effected
	• Limited amount of defect analysis conducted to say what the causes of sap burn are.
	• Harvest aide – damage not as bad because the fruit has to stand over for 1 day
	• Key: good supervision of picking staff
	• Do you need to wash off mango wash
	• Immerse fruit before de-sapping, reduces sap burn
	• Best system is the water/cherry picker
	  ○ Least Sap burn
	  ○ Greatest efficiency
	  ○ Good for bonus system
	• Poor knowledge by growers of Sap & shin browning.
	• Change conditions in the plant at harvest to reduce sap flow
		2
		
		2
			1	4
				
				5

Other defects	Lenticel/Russett/cleavage • What are the causes • What are the controls • Need clear definition of each defects, confusion at the moment. • *Monitor defects across growers to identify what the problem and levels of defects*			

PACK SHED				
Issue				
	Harvest 2.5 Fte's Shed 1 FTE Shed efficiency 20 trays/20 hour/man			
Labour	• No handle on the labour input within the shed • No logic in picking with stems on			
Reliability	Pull out fruit that is out of grade & put it into grade.			
Grading	• Pre- cool before grading • Conflict of data – i.e. Scott ledger says to cool after • What is the better mangoes recommendation for other varieties • Capacity of on farm fan forced cooling systems need to increase			
Box design	• Current boxes not fit for the purpose i.e. they collages • Information from the markets on % of box collapses. • Need independent assess on box quality			
1 touch	• Chains want to increase their efficiency, but no consideration for the packer			
Dips	• Limited efficacy of post harvest dips • Disposal of dips an environmental concern			
Benchmarking	• Packaging shed have access to a lot of data suitable for benchmarking; o Yield per block o Quality per block o Quality per harvesting system o Efficiency data on grading systems o Electronic selling systems			
WPHS				
Opportunities	What are the opportunities to put new technologies (colour – imaging) in pack sheds			

Bundaberg Meeting, 17th April 2005

Present:

Industry	**Industry**	**Facilitators**
Col Jeacocke: Gin Gin	Vin Brown: Burnett	Terry Campbell
Chris Allen: Burnett		Bob Williams

ORCHARD ESTABLISHMENT				
Issue		**Knowledge**	**Confidence**	**Impact**
Variety	• Saleability • Production consistent between years and regions • Dwarf growing habit • Disease resistance • Timing of maturity (January to February)	3	1	5
Land Preparation	• Consider needs at Harvest time. Good road ways and room to turn • Laser	2	3	

Orchard design	• Orientation - western face
	• Aim for max. kg/ha
	• Growing habit determines layout
	  ○ Slow – high density
	  ○ Fast – low density.
		3
		
		4
			
			4
				5
				
				5

Irrigation	• What is the water requirement for appropriate tree development • Monitoring equipment – confident information is available. • Relationship between water in soil and water in plant;	4	4	4
Nutrition	• Need to keep plant healthy • Soil Tests	4	4	4

Pruning	• Structure – important to start early
	  ○ Open tree off the ground
	  ○ Branching close to the ground
		4	4	5

Windbreaks	• Design
	  ○ for disease control (bacterial black spot)
	  ○ Fruit quality (fruit rub)
	  ○ minimise spray drift
	• Species
	• Root penetration into neighbouring rows
	• Frost damage id no wind flow
		
		2
		
		2
			
			2
			
			2
				
				5
				
				5

HARVEST TO HARVEST				
Issue		**Knowledge**	**Confidence**	**Impact**

Nutrition	• Where are trees feeding from
	• How reliable are leaf and soil analysis. Need to be regionally and variety specific, not generic.
	• If you get it wrong, you do not know for a number of years
	• Nitrogen
	  ○ How much and when
	  ○ Leaf sample in May/June (no effect on Flush)
	  ○ Leaf colour
		3	1	5

Irrigation	• To keep roots in good condition – irrigate all year round (Bundaberg). Do not irrigate in winter (Mundubbera). • No correlation between monitoring systems and what the tree wants. • Need to know $ of Fruit/Ml of water. • Nutrition/irrigation go hand in hand	2	2	4
Disease	• How do we know what level of disease do we have at any stage of the crop cycle. • Aim to do away with post harvest dips	2	2	5

Sunburn	• Losses 10 – 30%
	• Red skin varieties very susceptible
	• Spray additives may increase sunburn
	• Suggested strategies
	  ○ Orchard design – east/west
	  ○ Balance in leaf canopy			

	HARVEST			
Issue				
Timing	• Timing - Flesh colour/Blush/Fullness Number of ripe fruit/tree			
Crop Forecasting	• Maybe worth completing the data set • Prove that it works in Bundaberg			

Labour	• Getting them
	• Systems to educate them
	  ○ Video on what to look for eg Sap Burn
	  ○ Clothing needed
	  ○ Poster for shed (like the Lychee poster)
	  ○ Safety – tractors and PTO shafts
		2	5	5

Harvest	• Drop of fruit – accumulation of bouncing • Why does sap occur • Sunburn • Keep fruit cool • Skin browning – sporadic –Why • Rain ??? Why KP so susceptible • Transport of fruit to the shed • Something to toughen fruit skin • Benchmark harvest aides • Can we come up with a better harvest aid	1	5	5

Defects	• Need clear definition of each defect – too many standards out there
	• Only need 1 (Woolworths)
	• Brush damage
	  o Chilling
	  o Soft skin
	  o Poor nutrition
	  o Air movement over fruit
	• Common weight for pack size
	  o Standardise for each variety
		3
		
		2
		
		1
			2
			
			1
			
			1
				4
				
				5
				
				5

PACK SHED				
Labour	• No de-sappers in Bundaberg • 14-18 trays/hr/FTE			
Box design	• Auto box fillers would be good			
1 touch	• Chains want to increase their efficiency, but no consideration for the packer			
Dips	• Hot dips – equipment not good enough • Dips not working at 52 deg	4	2	4

Mareeba Meeting, 15th March 2005

Present:

Industry	**Interviewed**	**Facilitators**
John Nucifora	John Gambino	Rowland Holmes
Peter Delis	John Falvo	Irene Kernot
Ian Leighton	Bruce Nastasi	

Issue	**Key points**	**Confidence**
Variety	• New varieties must be disease resistant	
Planting spacing	• 9 x 8 • Preference for wider tree spacing, increase airflow to minimise disease levels • Individual tree better than hedgerows	
Disease	• What is the relationship between inoculum levels and disease control • Need greater knowledge on the mode of action of chemicals • Correct timing of fungicide applications • Disease thresholds in relation to fruit quality (and saleable life index) • Appropriate pesticide application for various pests	
Insect Pests	• Generally confident can identify or use a consultant	
Irrigation	• Improved irrigation monitoring has reduced sunburn. • Many growers use irrigation monitoring equipment (serviced by local consultant) • Those who use them are getting the benefits in improved fruit quality and yield	
Nutrition	• Applying Nitrogen is a bit of a gut feel • Need better information of sap tests • Lenticel spotting maybe linked to poor or inappropriate nutrition • Timing of nutrients and their interaction are an issue	
Shelf Life	• Need up to six weeks especially for exports	
Harvest	• Need for a Brix test for maturity index • Need more effective post harvest treatments • Amistar working well. • Spin Flo not working	
Harvest Aids	• Need for a study on the cost and quality comparison between harvest aids and destemming in the packing shed ○ Needs to identify all the critical issues to success of each operation	
Labour	• Can't get people to work	
General Comments	• Majority of Mareeba/Dimbulah growers have more than one commodity, eg avocadoes, citrus, vegetables. • When growers are doing well they attend meeting, when times are poor they don't.	

Appendix III

Critical Points and Critical Questions from RD&E Extraction Workshops

Orchard Establishment

Topic	Critical Points Raised	Critical Questions

Variety.	• Saleability
	• Productivity
	  o Consistent
	  o pack-out
	  o Targeted consumer
	• Growth habit – dwarf
	• Disease resistance
	• Timing of maturity
	• Need to have a spread of varieties, so that harvest is spread out over a period of time.
	• 35 to 45 days fruit shelf life
	• Technical support available for each new variety eg like B74 - agronomic and post harvest
		What other variety could I grow for my region?

Rootstock	• Generally very good appreciation that rootstocks are beneficial and would be prepared to pay a higher price for plants if the rootstock was superior. • Reduced precocity • Readily increase carbohydrates. • Disease control • Increase uptake of nutrients • Uniformity of flowering • Reduced biennial bearing.	

Soil Type	• Soil structure
	  o Uniformity
	  o Manage the site to suit soil. General information is available but not specific.
	• Need sandy, light, gravely soil: results in superior fruit quality
	• Not an issue for processing fruit
	• More effort managing non-suitable soil types	

Orchard Establishment

Topic	Critical Points Raised	Critical Questions
Water	• Water availability and quality • Impacting on nutrition • pH, salinity, quantity, reliability, hardness • Water pH is a major problem. High in Ca 7.0 to 8.5 pH in both Kununurra and Katherine. • Causes problems with foliar sprays and many use rain water specific for this. • Ca causes blockage in irrigation pipes and sprinklers • High pH reduces the availability of some nutrients.	

Access	• Access, impacting on infrastructure
	• Environment
	  ○ Urban encroachment
	  ○ Heritage/ native title	

Orchard Design	• Spacing 12x8, 10x8 (100-120 trees/ha), 9x8
	• Aim for maximum kg/ha
	• High density vs. low density – locality specific eg
	  ○ Low density plantings – warmer areas
	  ○ High density plantings – cooler areas
	• Labour efficiency
	• Orientation north/south or east/west. Orientation for western face.
	• East/West. Adjusted by region for the path of the sun around harvest time.
	• This is to minimise Sunburn
	• This is knowledge from experience and not from research in mango
	• Prune both ways to maximise surface area per hectare, This will increase the yield of blushed fruit
	• Good to be able to harvest one side then couple weeks later the other.
	• Preference for wider tree spacing, increase airflow to minimise disease levels	

Orchard Establishment

Topic	Critical Points Raised	Critical Questions
Land Preparation	• Laser preparation. No moulding as problem with harvest aids • Consider needs at Harvest time. Good road ways and room to turn	

Irrigation	• All would prefer mini sprinkler.
	• Irrigation must provide water into the row spacing to encourage grass cover (Jarra grass in Katherine). Grass is linked to soil health and development of beneficial insects. (not sure what the beneficial's actually are)
	• New establishments utilise irrigation monitoring devices and feel that they have a good understand of their operation.
	• Good service for moisture monitoring equipment only in those areas where there are consultants.
	• Correlate data with crop factor and pan evaporation.
	• Do not know what is happening in the plant. Need gadget to easily measure water flow in the plant.
	• Sprinklers, that are adaptable as the trees grow
	• Minimum cost system
	• Water the whole block in a day
	• Sprinkler/Drip – Wettable area determined by;
	  ○ Row orientation
	  ○ Sprinkler placement
	• Impacts on sunburn – what is the impact of humidity
	• Location may determine the type of irrigation that is needed..
	• No rural water use efficiency project in NT
	• Monitoring equipment – confident information is available.
		What is the water requirement for appropriate tree development
		
		Relationship between water in soil and water in plant;
		○ Inconsistent results between CSIRO and DBRID
		○ This has a big impact on the design of the irrigation system
		
		Baseline data on;
		○ Heat/leaf wetness/climate
		
		What are the events that trigger responses in the plant?
		
		What is the correlation between moisture monitoring equipment and what are the plants actually needs to ensure optimum productivity and fruit quality?

Nutrition	• Current recommendations are OK • When the plant is young - easy • Many growers are moving to biological fertilisers, but have limited confidence in them	What are the benefits of biological fertilisers over conventional fertilisers?

Orchard Establishment

Topic	Critical Points Raised	Critical Questions
Herbicides	• Soil pH causes problems with pre-emergent herbicides i.e. Surflan/simazine have been used, but not happy with the control. Use glyphosate and sprayseed. Sometime include Goal. • In the new large plantations, generally have to spray every 6 to 8 weeks. • Concerned about the impact of glyphosate on young plants. • Mulch has a significant benefit on weed growth and reduction in water demand. • Need for good consistent pre-emergent	What is a suitable weed control strategy (including pre-emergent herbicide) for control of grasses and broadleaves in tropical conditions?
Tree Architecture	• Structure – what is best for the type of marketing system? I.e. processing or 45 days shelf life. • Timing of hedging, in relation to the plant phenology. • Need to get the height of first branching right. • Aim for 3 to 5 branches to increase fruiting points. • Aim for about 1m above the ground. • Trunk sunburn in young plants is an issue. Trunks are painted with white wash or white plastic paint. Sometimes include copper fungicide to reduce fungal infection. • Not sure when to start to tip prune. • For spraying and later structure	Document case study for a range of systems and look at possibilities. (Information maybe out there).
Windbreaks	• Limited knowledge for mango o Does it reduce wind rob? o Does it reduce water loss? o Does it increase fruit quality? • Root penetration into the orchard. • Frost damage can be higher with wind breaks because no wind flow.	What are the best o Species? o Planting density? o What is the impact on beneficial -ve or +ve? There maybe generic data available for other crops that could be extrapolated. Have discussion paper developed, then possibility do developmental work
Disease	• Need to start managing disease early in the plants growth. o Bacterial black spot o Anthracnose	
Insect	• New Flush – caterpillar damage • Flattids and scale.	

Harvest to Harvest

Topic	Critical Points Raised	Critical Questions
Labour	• Supervisors best ratio of 1:5 minimum • Accommodation • Access • Immigration (region specific) • Allergy to mango sap • WHS/Induction	How can agronomic practices maximise productivity and minimise labour requirements
Pruning	• Timing, when the contractor is available • How often?, all of the tree every year or not • What are the benefits of tip pruning, root pruning (if and when), Chemical options • What are the best systems to use to set up the trees to minimise labour • Flush in May (Bundaberg) not desirable, information on burning off with Ethrel • Pruning in relation to carbohydrates • Readily available vapour pressure deficits during these times, to indicate that the plant is functioning. Need easy systems for measuring this (gadget). • How much canopy is necessary for light interception. What leaves are functioning and when. • Disease management through pruning is critical. • Does pruning improve fruit quality? • What is the optimum time to prune: in relation to time, phenology, season, carbohydrate load etc. • What is the long term effect of pruning on disease levels in relation to the need to apply curative fungicides? - In relation to inoculum levels and comments by chemical reps	What is the critical time to prune (by region & variety) to achieve o Optimum flush development. o Maximum flower development. o Maximum fruit quality o Minimum disease development o Optimum tree structure to maximise labour efficiency. What are the critical issues with pruning; • Optimum canopy area to light capture • Carbohydrate levels within the plant • Pruning methods. • Sun burn management for the tree and fruit. Which leaves contribute most to yield? (i.e.. young or old)

Harvest to Harvest

Topic	Critical Points Raised	Critical Questions

Nutrition	• Considered to biggest impact on tree health, productivity & fruit quality.
	• What is the best time to do leaf and soil analysis?
	• What is the effect of fertiliser application on the ground on the uptake into the tree?
	• What is influencing fruit drop and fruit retention?
	• What micronutrient concentrations are needed for optimum yield?
	• What effect do residual soil fertiliser applications (previous year/season) have on the tree?
	• How should we manage nitrogen fertilisation for optimum balance of yield and quality?
	• How do we get calcium into our mango trees?
	• Regionally based recommendations.
	• High pH soils.
	• Soil Health may improve conditions
	• Nitrogen, potassium, and calcium.
	  ○ Timing
	  ○ Quality
	  ○ Total amounts in the soil
	  ○ Availability to the plant
	• N:P:K ratio's for mangoes Generic data available only
	• TE eg B and Zn plus others.
	• Growers are playing with nutrition but there are big gaps
	• All information in Ag notes is not good.
	• Where are trees feeding from?
	• Can get it wrong and not know for a number of years.
		What are the optimum nutritional requirements for mango (by region and variety), to achieve maximum yield, fruit quality and fruit shelf life?
		Inputs
		• Timing
		• Amounts
		• Application methods
		Outputs
		• Pollen viability
		• Fruit retention
		• Fruit quality
		• Lenticel spotting
		• Disease levels
		
		What are the appropriate monitoring tools and systems available to determine the nutritional status of a mango plant?
		• Leaf and soil analysis
		• Sap
		• other
		Can sap testing for particular elements be used to determine the level of flowering? (Can elements then be manipulated to improve flowering?)
		What are the factors affecting lenticel spotting? (nutrition, weather, tree age, irrigation etc.)
		What is the impact of nutrition on flowering & fruit set? (% hermaphrodite flowers, pollen, nectar flow etc.)
		What level of boron is needed for flowering & pollination?

Harvest to Harvest

Topic	Critical Points Raised	Critical Questions

Irrigation	• In regard to the phenology cycle there is a lot of unknowns when to stress and not to stress and the impact these decisions have on yield and quality.
	• Relationship between water in soil and water in plant;
	  ○ Inconsistent results between research agencies.
	  ○ This has a big impact on the design of the irrigation system
	• Baseline data on;
	  ○ Heat/leaf wetness/climate
	• What are the events that trigger responses in the plant?
		What are the optimum irrigation requirements for mango (by region and variety), to achieve maximum yield, fruit quality and fruit shelf life?
		Inputs
		• Timing
		• Amounts
		• Application methods
		Outputs
		• Flush
		• Flowering
		• Fruit retention
		• Fruit quality
		• Shelf life
		What are the appropriate monitoring tools and systems available to determine the water status in a mango plant?

Growth Regulators	• What is the correct timing – End of 1st Flush? • Temperature is very hot when application is necessary and plants have stopped photosynthesis (vapour pressure deficits), therefore limited success (Kununurra). • Application methods, in regard to root development. i.e.. phenology cycle of Whiley is based on subtropical mangoes. • Need to redo the phenology work (some of this work may have been done by CSIRO, need to check) • What is the accumulation effect of paclobutrazol	What is the optimum frequency and application rate (by region and variety) to achieve maximum benefit from paclobutrazol or similar PGR's?
Flowering/ Pollination	• What are the pollinators?? What are the key pollinators and when do they work. • Viability of pollen (work from the breeding program has indicated that pollen is only viable in the tropics for a very short time (2 hours). This may have a significant impact on productivity. • Number of male vs. female flowers. • What is the impact of temperature on the M/F ratio. • What is the impact of nutrition on pollen viability	What are the key principles to achieve maximum pollination in KP?

- This problem appears to be specific to KP.

	Terminal development	Flower development	Fruit set	Fruit retention	Accumulated fruit number
Optimum	100	90	100	80	72
Actual B74	80	70	150	70	52
Actual KP	80	30	60	30	4.2

Harvest to Harvest

<table>
<tr><th>Topic</th><th>Critical Points Raised</th><th>Critical Questions</th></tr>
<tr><td>Flush</td><td>

How do you turn a flush on/ turn a flush off?
Flowering is a function of

Flush age & temperature (knowledge is not complete, need more information)
Flush age >30 days – leaf maturity

In NT, have to be careful not to cause flushing too early, because it is then difficult to stop.
What are the critical factors in the fruit/plant that is giving high fruit quality
Canopy to fruit ratio is not known in mango. In kiwi fruit it is know that at pruning time 6 leaves are necessary. Ian Bally has done some research on Keitt that indicates that the greater the fruit to leaf ratio the better the fruit quality. This type of information is needed for Mango. Suggest a survey first of specific pruning practices.
How can you force a tree to flush?
How does carbohydrate level affect tree growth?
How can carbohydrate levels be used as a monitoring tool?

What past research work has been done in this area?
Is there an opportunity to develop a quick test?

</td><td>
What strategies can be used to manipulate flushing patterns?

Chemical (Plant Growth Regulators, hormones, etc),
Canopy management
Root pruning
Sintering
Nutrition/Irrigation
Root stocks

What is the optimum canopy area to fruit ratio for mango (by region & variety) to deliver maximum yield and fruit quality?

What monitoring tools are available to readily determine the best strategy to implement?

Vapour pressure deficient?
Carbohydrate level?
Leaf brix level?

X,Y, & Z are new tools that need to be developed that can be used to enhance the control over flushing and ensure uniform flowering.
<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>PGR</td><td>X</td><td>Y</td><td>Z</td></tr>
<tr><td>Pruning</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nutrition</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Irrigation</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Climate</td><td></td><td></td><td></td><td></td></tr>
</table>
Need to be able to manipulate flowering via pruning etc so that flowering & harvest be regulated. Target eg sequential flowering.
<table>
<tr><th colspan="5">Block Number</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>1st flowering & harvest</td><td>2nd flowering & harvest</td><td>3rd flowering & harvest</td><td>4th flowering & harvest</td><td>5th flowering & harvest</td></tr>
</table>
</td></tr>
</table>

Harvest to Harvest

Topic	Critical Points Raised	Critical Questions
Insect Pests	• Monitoring and economic threshold levels are unknown. • What is the EIL of insect damage on the flush • Impacts of seed weevil at flushing time are unknown. • Do not have IPM systems or the tools. • How much pest damage (tip borers, leaf feeding caterpillars, swarming beetles etc.) can the tree sustain without impacting on yield?	What are the economic threshold level of insect pests of mango (by region and Variety)? What are the IPM practices required to manage insect pest population (by region by variety)?

Disease	• Major issue across all regions with higher disease pressure in the warmer humid regions.
	• Disease management is critical in regard to export
	• In high density planting disease management maybe more critical
	  ○ SER
	  ○ Alternaria
	  ○ Anthracnose
	  ○ Disorder – X.
	• Up to Flowering and onwards
	  ○ What should be done to reduce disease inoculation levels
	  ○ What diseases effect fruit set
	• Need major focus on application equipment, particularly at low volumes.
	• What is the long term effect of pruning on disease levels in relation to the need to apply curative fungicides? - In relation to inoculum levels and comments by chemical reps
	• Pesticide compatibility (Can Amistar be mixed with dimethoate, copper, mancozeb and still work or be active?)
	• How does weather impact on disease inoculum levels?
		What are the economic threshold level of the various diseases of mango (by region and Variety)?
		
		What are the IDM practices required to manage disease (by region by variety)? IDM needed
		  ○ Fungicide resistance
		  ○ Alternative pre/post harvest fungicides not good (except for Amistar.
		  ○ Need alternatives to diathane/copper
		  ○ Monitoring protocol
		
		What is the appropriate application technique for the various diseases?
		
		What is the compatibility (efficacy and crop safety) of pesticides registered in mango?

Harvest to Harvest

Topic	Critical Points Raised	Critical Questions
Sun Burn	• 20 to 30% unsaleable fruit on most trees in all regions. • All varieties effected. • Is the ability of the plant to supply sufficient water on the sunny side the issue? • Red shinned varieties more susceptible • Spray additives may increase sunburn • Orchard orientation may reduce • Balance in leaf canopy.	What are the Management strategies that minimise sunburn. • orchard orientation? • Canopy/light interception ratio? • Pruning strategy? • Pesticide applications?

Harvest

Topic	Critical Points Raised	Critical Questions

Criteria for Maturity	• Need to have a quantitative/objective measure, so that there is a correlation between the field and end user (wholesaler).
	  ○ Long term objective for a quantitative measure
	  ○ Short term objective, empowering growers and wholesalers in communication. Change management
	• Assess the possibility of specific gravity (density) and a method of sorting out immature fruit in the packaging shed. (refer to some work that Yan started).
	• Key criteria
	  ○ Heat sums – particularly for planning
	  ○ Dry matter (not applicable for all varieties)
	  ○ Flesh colour
	  ○ Specific gravity (been around for a while with little confidence)
	  ○ Hand feel (fullness of fruit)
	  ○ Milk/sugar spotting
	  ○
	• Would like to have a rapid quantitative non-destructive test that could be a industry standard.
	• NIR/colorimetry would reduce the % class variations in a box. I.e. reduce the incidence of 1 class 2 fruit in a class 1 box or a class 1 fruit on a class 2 box.
	• Depends on where you intend on selling your fruit
	• Can a Brix test for mangoes be developed? (particularly for R2E2 to avoid early harvest affecting taste)
		What is a desirable fruit maturity index for mango that could be developed as an industry standard?

Crop forecasting	• Valuable for planning labour, transport logistics, supplies • How can we get an early estimation of yield? • Need to complete the data set by covering all of Australia.	How valuable is this tool across all production areas? Could this be included in a maturity index standard?

Harvest

Topic	Critical Points Raised	Critical Questions

Sap	• 20 – 30% of class 2 effected
	• Limited amount of defect analysis conducted to say what the causes of sap burn are.
	• Harvest aide – damage not as bad because the fruit has to stand over for 1 day
	• Key: good supervision of picking staff
	• Do you need to wash off mango wash
	• Immerse fruit before de-sapping, reduces sap burn
	• Best system is the water/cherry picker
	  o Least Sap burn
	  o Greatest efficiency
	  o Good for bonus system
	• Poor knowledge by growers of Sap & shin browning.
	• Change conditions in the plant at harvest to reduce Sap flow.
	• Need to quantity the benefit of leaving stem/button on mango for SER control/reduction/delay onset, compared to removing stem
	• With short cut stems, fruit can go through the graders.
		What causes sap burn and how is it best controlled?

Harvest aid	• Development of harvest aids has seen a significant reduction in harvest labour, desapping labour, and a greater efficiency of existing field labour. • Easier on the workers, less numbers of staff • Do they increase the damage to the fruit • What is the difference in cost and quality between harvest aids and de-stemming in the packing shed? • What are the critical issues that lead to the success of each operation?	What is the accumulated impact of “bouncing” fruit through the harvest and packaging process on fruit shelf life and quality?

Harvest

Topic	Critical Points Raised	Critical Questions
Cherry Pickers	• Picks more per person than a harvest aid machine with a picking crew (average per person on the crew) • People are working as individuals rather than part of a team Positives • All of the fruit is hand picked • Harvest more fruit per tree • More economical • Double the productivity of a person • Know exactly who is picking what • Pickers are closer to the fruit to estimate fruit maturity • Top of the trees mature first so can pick this fruit at the optimum time • Can spot pick earlier with smaller teams Negatives • Higher maintenance, high capital cost • Water replenishment • Training and skill level is much high for people to drive a Cherry picker • Need to keep the extended height below 3m to reduce the WHS issues you are dealing with (still get an extra 2m reach with a person) • If you want 20 pickers, you need to interview 100, trial 60 • More tree damage and irrigation lines	

Harvest

Topic	Critical Points Raised	Critical Questions
Defects	Lenticel/Russet/cleavage • What are the causes • What are the controls • Need clear definition of each defect, confusion at the moment. • Monitor defects across growers to identify what the problem and levels of defects. • What are the factors affecting lenticel spotting? (nutrition, weather, tree age, irrigation etc.)	Need one industry standard on description of fruit defects.

Labour	• Staff
	  ○ Finding, recruiting, training, retaining them
	  ○ Want to minimise the number of staff needed and maximise the efficiency of what we have	

Packaging Shed

Topic	Critical Points Raised	Critical Questions
Hot Dips	• Limited efficacy of post harvest dips • Disposal of dips an environmental concern • Hot dips – equipment not good enough • Dips not working at 52°C	Why spend money heating fruit up, and then have to cool down. Get rid of post harvest treatments Does heating (hot dip) impact on shelf life (ripening & disease) in relation to long-term storage o Does heat negatively impact? What effect does a hot dip have on fruit shelf life (physiologically)
Computerised Grading and labelling	• Increases efficiency in the shed and office. • Traceability • Maintenance & service of equipment is a problem.	With computerised packaging and labelling, shed have access to a lot of data suitable for benchmarking; o Yield per block o Quality per block o Quality per harvesting system o Efficiency data on grading systems o Electronic selling systems
Labour	• No handle on the labour input within the shed • No logic in picking with stems on. • No de-sappers in Bundaberg	
Grading	• Reliability to pull out fruit that is out of grade & put it into grade Pre- cool before grading • Conflict of data – i.e. Scott ledger says to cool after • Capacity of on farm fan forced cooling systems need to increase	What is the better mangoes recommendation for other varieties?
Box design	• Current boxes not fit for the purpose i.e. they collages • Information from the markets on % of box collapses. • Need independent assess on box quality • Auto box fillers would be good	
1 touch	• Chains want to increase their efficiency, but no consideration for the packer.	
Opportunities	What are the opportunities to put new technologies (colour – imaging) in pack sheds	

Appendix IV

Table 9. Current Projects within the Research Providers Delivering Outcomes to the Mango Industry

Project title	Agency	Project Leader	Start Date	End Date	Key Outcomes
Management of post harvest diseases of subtropical and tropical fruit using their natural resistance mechanisms.	ACIAR	Dr Lindy Coates	01/07/02	30/06/05	Increased knowledge of preformed and induced defence mechanisms in mango and avocado fruit Identification of treatments which elicit defence responses and reduce anthracnose and stem-end rot in mango and avocado fruit
Management of post harvest diseases of subtropical and tropical fruit using their natural resistance mechanisms. – Phase II Extension	ACIAR	Dr Chrys Akem	01/07/04	30/12/06	Evaluation data on the efficacy of plant defence compounds for control of field and post harvest diseases. Recommendations for treatment combinations, which may: elicit field defence responses, affect field disease effects and reduce anthracnose and stem-end-rot in mango fruit.
Integrated pest management and supply chain improvement for mangoes in the Philippines and Australia	ACIAR	Mr Rod Jordan	01/01/05	30/06/08	Data and recommendations on potential attractants for insect traps for fruit spotting bug Data and recommendations on alternative control measures and pest specific chemicals to reduce reliance on broad spectrum chemicals. Revised IPM and spray recommendations that incorporate project findings and farmer/spray operator perspectives. Data and recommendations on use of potential attractants for insect traps and other control options for mango seed weevil.

					Preliminary assessment data on X ray technologies for the detecting pulp weevil and mango seed weevil. Assessment data on survey methodologies and limited survey data. Report on discussions of findings/data with relevant authorities for accessing to target markets.
To expand access for mangoes from the Philippines in markets which require freedom from seed and pulp weevils.	AusAID	Mr Bruno Pinese	01/10/05	01/10/08	Agreed and verified survey methodology for seed and pulp weevil in Mindanao and Queensland. A complete record of seed and pulp weevil presence/absence in the Davao Region (Davao del Sur Province) in Mindanao and, subject to future support, data for other areas in Mindanao in years 2 and 3 plus an assessment of how frequently surveys need to be conducted to maintain 'area freedom' status. Comprehensive data set of survey results ready for submission to relevant authorities for assessment of market access to appropriate markets. Mutually agreed (and endorsed by Biosecurity Australia (BA)) survey methodology for mango seed and pulp weevil. Absence of weevils in area surveys is a critical determinant of market access approval. Increased knowledge of biology, ecology and control possibilities of mango seed and pulp weevils. Stronger linkages for biosecurity co-operation, information sharing and collaboration between BPI/LGU, DPI&F, and BA.

Biology, damage levels and control of Red Banded Mango Caterpillar in Papua New Guinea	ACIAR	Mr Bruno Pinese	01/0/02	31/08/05	Develop and evaluation pheromones as a tool to trap RBMC population for crop monitoring and quarantine surveillance. Knowledge of RBMC life cycle and host range to increased capacity to manipulate to organism and determines advantageous timing for control measures. Evaluation of a range of pesticides compatible with current IPM systems in preparedness of an incursion.
Mango Plant Protection Phase I	HAL	Mr Bruno Pinese	01/07/02	30/06/05	Development of better management strategies through the increased knowledge of mango insect pests and diseases. Expanded market opportunities local and export with reduced pesticide use. Improved preparedness against future incursions of Red Banded Mango Caterpillar. Improved OH&S outcomes though less operator exposure to toxic pesticides during treatment applications. Potential problems with chemical treatment interaction compromising interstate quarantine requirements will be avoided.
Mango Crop forecasting	HAL	Mr Greg Owens NTDPI	2001	2007	Crop forecasting methodology Industry coordination and cooperation in the mango season

Table 10. Impact Assessment by Growers

Rating by Growers		Cost			Quality & Yield			Needs		Ranking	
Practices		Actual % of Production Cost	Potential for Improvement with RD&E	Cost Priorities	Impact	Knowledge	Confidence in Information	Need to improve current knowledge available	Need to Improve information of existing best practice	Ranking R&D	Ranking for Information
Irrigation	Total	1.7	2	3.4	4.0	3.0	2.0	40.8	54.4	**5**	**5**
Nutrition	Total	3.9	3	11.7	5.0	3.0	2.0	175.5	234.0	**2**	**2**
Disease Control	Total	5.1	3	15.3	5.0	1.0	2.0	382.5	306.0	**1**	**1**
Insect Control	Total	3.1	3	9.3	3.0	2.0	3.0	111.6	83.7	**3**	**4**
Canopy Management	Total	4.6	2	9.2	4.0	3.0	2.0	110.4	147.2	**3**	**3**
Plant Growth Regulator	Total	2.9	2	5.8	3.0	3.0	3.0	52.2	52.2	**5**	**5**
Harvest	Crop Forecasting	21.5	3	64.5	4	3	3	774.0	774.0	**3**	**2**
	Maturity Index	21.5	3	64.5	4	2	3	1032.0	774.0	**1**	**2**
	Harvest Aids	21.5	3	64.5	5	3	3	967.5	967.5	**2**	**1**
	Labour				?	?	?				
Packaging Shed	Post Harvest Treatments	56.0	3	168	3	2	2	2016.0	2016.0	1	1
	Grading Equipment	56.0	3	168	3	3	3	1512.0	1512.0	2	2
	Labour				?	?	?				

Table 11. Impact Assessment by Researchers

Rating by Researchers		Cost				Quality			Yield				Needs			Priorities			Ranking (8)		
Prod Practices	Phenological Timing	Actual % of Production Cost (1)	Cost rating (2)	Potential for Improvement with RD&E (3)	Cost Priorities (4)	Impact on Quality (2)	Potential for Improvement with RD&E (3)	Quality Priorities (5)	Impact on Yield (2)	Potential for Improvement with RD&E (3)	Yield Priorities (5)	Quality x Yield (6)	Need to improve current knowledge available (3)	Need to Improve adoption of existing best practice (3)	Need to Improve information of existing best practice (3)	Priorities for R&D (7)	Priorities for Adoption (7)	Priorities for Information (7)	Ranking R&D	Ranking Adoption	Ranking for Information
Irrigation																					
	Post Harvest					2	1	2	2	2	4	27	2	3	4	54	82	109	na	na	na
	Vegetative Development					4	1	4	3	2	6	82	2	4	4	163	326	326	na	na	na
	Panicle Development					3	1	3	2	2	4	41	2	3	4	82	122	163	na	na	na
	Flowering					4	2	8	4	2	8	218	2	3	4	435	653	870	na	na	na
	Pollination/Fruit Set					4	2	8	4	2	8	218	2	3	4	435	653	870	na	na	na
	Fruit retention					4	2	8	4	2	8	218	2	3	4	435	653	870	na	na	na
	Fruit Development					4	2	8	4	2	8	218	2	3	4	435	653	870	na	na	na
	Fruit Maturity					4	2	8	2	2	4	109	2	3	4	218	326	435	na	na	na
	Total	1.7	2	2	3.4	3.6	1.6	6.1	3.1	2.0	6.25	130	2.0	3.1	4.0	**260**	**407**	**521**	**5**	**4**	**5**
Nutrition																					
	Post Harvest					3	2	6	3	2	6	421	2	3	4.5	842	1264	1895	20	19	19
	Vegetative Development					3	3	9	3	3	9	948	2	3	4.5	1895	2843	4265	16	16	12
	Panicle Development					4	3	12	3	3	9	1264	2	3	4.5	2527	3791	5686	12	9	8
	Flowering					4	3	12	3	3	9	1264	2	3	4.5	2527	3791	5686	12	9	8
	Pollination/Fruit Set					4	3	12	3	3	9	1264	2	3	4.5	2527	3791	5686	12	9	8
	Fruit retention					3	3	9	2	3	6	632	2	3	4.5	1264	1895	2843	19	17	17
	Fruit Development					4	3	12	2	1	2	281	2	3	4.5	562	842	1264	na	na	na
	Fruit Maturity					3	3	9	1	1	1	105	2	3	4.5	211	316	474	na	na	na
	Total	3.9	3	3	11.7	3.5	2.9	10.1	2.5	2.4	5.9375	703	2.0	3.0	4.5	**1407**	**2110**	**3165**	**2**	**2**	**2**
Disease Control																					
	Post Harvest					3	3	9	2	3	6	826	4	4	4	3305	3305	3305	9	13	15
	Vegetative Development					3	3	9	2	3	6	826	4	4	4	3305	3305	3305	9	13	15
	Panicle Development					5	4	20	3	3	9	2754	4	3	4	11016	8262	11016	4	4	4
	Flowering					5	4	20	5	3	15	4590	4	3	4	18360	13770	18360	1	1	1
	Pollination/Fruit Set					5	4	20	5	3	15	4590	4	3	4	18360	13770	18360	1	1	1
	Fruit retention					5	4	20	5	3	15	4590	4	3	4	18360	13770	18360	1	1	1
	Fruit Development					4	4	16	3	3	9	2203	4	3	4	8813	6610	8813	5	6	5
	Fruit Maturity					4	4	16	3	3	9	2203	4	3	4	8813	6610	8813	5	6	5
	Total	5.1	3	3	15.3	4.3	3.8	16.3	3.5	3.0	10.5	2611	4.0	3.3	4.0	**10442**	**8484**	**10442**	**1**	**1**	**1**

Table 2.

Rating by Researchers		Cost				Quality			Yield				Needs			Priorities			Ranking (8)		
Prod Practices	Phenological Timing	Actual % of Production Cost (1)	Cost rating (2)	Potential for Improvement with RD&E (3)	Cost Priorities (4)	Impact on Quality (2)	Potential for Improvement with RD&E (3)	Quality Priorities (5)	Impact on Yield (2)	Potential for Improvement with RD&E (3)	Yield Priorities (5)	Quality x Yield (6)	Need to improve current knowledge available (3)	Need to Improve adoption of existing best practice (3)	Need to Improve information of existing best practice (3)	Priorities for R&D (7)	Priorities for Adoption (7)	Priorities for Information (7)	Ranking R&D	Ranking Adoption	Ranking for Information
Insect Control																					
	Post Harvest					3	3	9	1	1	1	84	3	1	4	251	84	335	na	na	na
	Vegetative Development					2	2	4	1	1	1	37	1	1	4	37	37	149	na	na	na
	Panicle Development					1	1	1	1	1	1	9	1	1	4	9	9	37	na	na	na
	Flowering					2	2	4	2	2	4	149	3	3	4	446	446	595	na	na	na
	Pollination/Fruit Set					2	3	6	2	2	4	223	3	3	4	670	670	893	na	na	na
	Fruit retention					1	1	1	3	3	9	84	3	3	4	251	251	335	na	na	na
	Fruit Development					2	2	4	1	1	1	37	2	2	4	74	74	149	na	na	na
	Fruit Maturity					4	4	16	3	3	9	1339	4	4	4	5357	5357	5357	7	8	11
	Total	3.1	1	3	9.3	2.1	2.3	5.6	1.8	1.8	3.0625	160	2.5	2.3	4.0	**401**	**360**	**641**	**4**	**5**	**4**
Canopy Management																					
Mechanical/hand	Post Harvest					3	3	9	4	3	12	994	3	3	3.5	2981	2981	3478	11	15	14
ethyl	Vegetative Development					2	4	8	4	4	16	1178	2	3	3.5	2355	3533	4122	15	12	13
ethyl	Panicle Development					3	4	12	4	4	16	1766	3	4	3.5	5299	7066	6182	8	5	7
	Flowering					3	3	9	2	3	6	497	3	2	3.5	1490	994	1739	17	20	20
	Pollination/Fruit Set					2	2	4	2	2	4	147	2	2	3.5	294	294	515	na	na	na
hand pruning	Fruit retention					3	3	9	3	3	9	745	2	2	3.5	1490	1490	2608	17	18	18
	Fruit Development					2	2	4	2	2	4	147	2	2	3.5	294	294	515	na	na	na
	Fruit Maturity					2	2	4	2	2	4	147	2	2	3.5	294	294	515	na	na	na
	Total	4.6	2	2	9.2	2.5	2.9	7.4	2.9	2.9	8.265625	561	2.4	2.5	3.5	**1332**	**1402**	**1963**	**3**	**3**	**3**
Plant Growth Regulator																					
	Post Harvest					2	2	4	2	1	2	46	3	2	3	139	93	139	na	na	na
	Vegetative Development					2	2	4	2	2	4	93	3	2	3	278	186	278	na	na	na
	Panicle Development					2	2	4	3	2	6	139	3	2	3	418	278	418	na	na	na
	Flowering					3	2	6	3	2	6	209	3	2	3	626	418	626	na	na	na
	Pollination/Fruit Set					1	1	1	2	1	2	12	2	1	3	23	12	35	na	na	na
	Fruit retention					1	1	1	2	2	4	23	2	2	3	46	46	70	na	na	na
	Fruit Development					1	1	1	1	1	1	6	2	2	3	12	12	17	na	na	na
	Fruit Maturity					3	1	3	1	2	2	35	2	2	3	70	70	104	na	na	na
	Total	2.9	1	2	5.8	1.9	1.5	3.0	2.0	1.6	3.25	57	2.5	1.9	3.0	**141**	**106**	**170**	**6**	**6**	**6**

Table 12. Computations used in Tables 1 and 2.

Note 1. Cost of Production

	Francis Bright (AGWA)		Survey data (massaged)		Agrilink – Gross Margin		Agrilink – Discounted cash flow	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Irrigation	$659.31	6.7%	$441.00	4.2%	251.35	1.7%	$186.00	1.6%
Nutrition	$345.07	3.5%	$719.00	6.9%	583.28	3.9%	$783.06	6.9%
Disease	$415.75	4.2%	$666.00	6.4%	765.17	5.1%	$537.54	4.8%
Insect	$76.80	0.8%	$111.00	1.1%	467.14	3.1%	$318.06	2.8%
Canopy	$370.00	3.7%	$498.00	4.8%	685.80	4.6%	$498.48	4.4%
PGR	$380.00	3.8%	$380.00	3.6%	433.94	2.9%		0.0%
Harvest	$2,250.00	22.7%	$2,250.00	21.5%	3,213.50	21.5%		0.0%
Other**	$69.40	0.7%	$69.00	0.7%	177.12	1.2%	$161.82	1.4%
Packaging	$5,324.00	53.8%	$5,324.00	50.9%	8,370.50	56.0%	$8,814.54	78.0%
Totals	$9,890.33		$10,458.00		14,947.80		$11,299.50	

Note 2: Impact on Quality/Yield.

1 = Nil
2 = Low
3 = Medium
4 = High
5 = Critical

Note 3. Potential for Improvement with RD&E:

1 = Nil
2 = Minor
3 = Good
4 = Major
5 = Significant

Note 4. Cost Priorities. Ranking for Cost of Production x Ranking for Potential for Improvement with RD&E.
Note 5. Quality/Yield Priorities. Impact x Potential for Improvement
Note 6. [Quality/Yield] = Cost Priorities x Quality Priority x Yield Priority
Note 7. Need x [Quality/Yield