Improving fruit quality and profitability of 'Honey Gold' mango

Ted Winston
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Project Number: MG10009

MG10009

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E. C. Winston *et al.*

FINAL REPORT

Tropical Horticultural Consulting P/L, Mission Beach Qld 4852

Improving fruit quality and profitability of 'Honey Gold' ™ Mango

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'Honey Gold' is a relatively new mango cultivar. Market demand is strong and growing with both local and export markets being developed by Piñata Farms Pty Ltd. An earlier project MG06022 resolved several agronomic issues, including inconsistent flowering in tropical environments and low yield due to excessive fruit drop. However MG06022 identified other constraints impacting on grower profitability: (i) low percentage packout of premium grade fruit (ii) underskin browning, (iii) need for a good crop forecasting model, and (iv) need to develop alternative markets for non premium fruit. The objectives of MG10009 were to develop suitable production and handling methodologies to reduce these issues and improve grower profitability.

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MEDIA SUMMARY

Many 'Honey Gold' mango growers experience reduced profitability from low packouts of premium grade fruit. Initiatives to improve profitability by reducing under-skin browning (USB), increasing packout percentages, developing a crop forecasting model and finding alternative outlets for non-premium grade fruit have been conducted with MG10009 making significant contributions to improve grower profitability.

A downgrades analysis methodology was implemented and training provided for wholesalers and packhouse operators. Causes of downgrades were clarified and remedial action advised. Farm visits resulted in better pruning, greater attention to spraying, as well as more effective pest control during early fruit set. Fruit quality has improved over the life of the project.

Crop forecasting helps balance supply with customer/consumer demand and reduces risk of oversupply during critical periods. An effective crop forecasting model for 'Honey Gold' was developed with fruit reaching commercial maturity at 1,500 accumulated heat sums, from the time of initial fruit set (full flowering). This model allows growers and marketers to estimate the start of harvest well in advance and allow better planning of harvesting teams and marketing strategies.

USB develops as a bruise-like symptom under the mango skin several days after packing, and is particularly prevalent in fruit from hotter growing areas. 'Honey Gold' is particularly susceptible, but USB also affects 'R2E2' and 'Kensington Pride'. Work has found softer harvesting, gradual postharvest cooling of fruit, keeping temperatures about 16°C throughout the cold chain, and softer packing material all reduce USB incidence. Research confirmed night harvesting is likely to significantly reduce USB compared with afternoon harvested fruit. Minimal USB occurred in the final year of the project.

Pinata Farms have been developing alternative markets/uses for non premium fruit, thus removing these fruit from the fresh market. Export markets have been further developed with successful shipments to Hong Kong, Singapore, Canada and Russia with fruit also successfully supplied direct to Countdown New Zealand.

'Honey Gold' growers are kept informed of research and best practices through monthly critical inputs sheets, the annual 'Honey Gold' Congress, a *'Honey Gold' Best Practice Manual,* and by frequent farm visits/contact from either Pinata or Tropical Horticultural Consulting.

Additional work is needed to continue to build upon past USB work and leads. More efficient recording, summary and report back systems for both Down Grade Analysis and Crop Forecasting are required with greater on farm work to decrease causes of downgrade needed. Efforts need to continue to find alternative markets.

TECHNICAL SUMMARY

Downgrades analysis
To help improve packout percentages a downgrades analysis process was developed and implemented to determine causes of pre and postharvest defects. The procedures helped growers to clearly identify the defects causing downgrades, and potential control measures. Most downgrade defects were pre-harvest rather than postharvest. There were regional and farm to farm variations, but in general, sunburn and blemishes were the major causes of pre-harvest downgrading. Growers responded to the downgrade results by changing/improving management practices. Pruning and nutrition have improved on a number of farms and several properties made major changes to orchard sprayers to improve coverage.

The original packout objective was >70% premiums and 30% Class 1, however this did not include juice/bulk grade fruit which must be included as they are part of the yield. A commercially realistic target should be 60% premium, 30% class 1, and 10 % bulks/juice (60:30:10). This figure was achieved on several farms. However for several reasons, a number of farms had less than 50% premiums. In some instances, adverse weather was a factor but in others it is not.

The wide range in % premiums between farms and regions indicates more work is needed. Wetter areas will struggle to consistently achieve 60% premiums but they can improve. Improvements have been made on several farms by the hard work of the owners. In other instances, especially on smaller properties, growers lack finances and/or labour to improve practices.

Crop forecasting
Three years data over all mango growing areas has consistently shown that 1500 accumulated heat units provides a good guide to when 'Honey Gold' are ready for harvest based on 15% dry matter. Heat sums were calculated from the date of full flowering (Stage i) using the formula of Heat Sum = ((maximum °C + minimum °C)/2) – 12°C. Use of heat sums removes variables which can make other methods of maturity prediction less useful. However growers still need to evaluate fruit for shape and flesh colour before making the critical decision on when to harvest. Dry matter results proved an unreliable indicator of fruit maturity, mainly because of inconsistent adoption of testing procedures.

Underskin browning (USB)
Results from project MG06022 indicated under skin browning (USB) is often associated with rapid reduction in temperatures after harvest and physical damage to fruit caused during harvesting and packing, or from abrasion damage against tray inserts or trays during transport. Hence, a standard USB test that combined lightly abrading with sandpaper and placing at 13ºC was tested. Results showed that pulling the fruit over ½ sheet (70 mm long) of 220-240 grit sandpaper, holding at 12-13ºC for six days, then ripening, caused USB to develop on up to 80% of the fruit. Further refinement involved using a cheap, small orbital sander held in a pivot arm to apply a constant 105 gm of weight onto the fruit, and abrading for 1 sec while holding the fruit firm.

Observations suggested USB may be more severe in stressed fruit or in fruit with higher turgor pressure (e.g. fruit harvested in the early morning). Hence the effects of fruit growing in the sun-exposed areas of the canopy versus shaded, early morning versus mid afternoon, desapped versus

not desapped and fruit on the top of the field bins versus those near the bottom was tested. The effect of fruit maturity on USB was also examined.

Contrary to expectations, fruit harvested in the morning developed less USB after treatment with the standard USB test compared with those harvested in mid afternoon. Effects were significant and consistent across two farms, indicating a very promising avenue for USB control. Also fruit harvested three weeks before commercial maturity had significantly less USB but incidence increased at two weeks before, and at commercial maturity. This does not have commercial implications because fruit are harvested only after they have reached commercial maturity. There were no significant effects of sun versus shade, stems retained or removed, and position of fruit in the field bins.

A commercial sized trial to improve skin toughness with ten nutrition and water stress treatments failed to show any significant or consistent treatment effects on USB. None of the nutrition treatments gave a commercial level of USB control and leaf and skin mineral analysis gave inconsistent results. Water stress results were compromised by rain.

Two Katherine farms both in trial and commercial shipments have consistent and large differences in USB expression although the farms are only about 15 km apart. Why the difference is not known but there are number of factors differing between the farms and further investigation is warranted to identify how to grow more robust fruit.

Semi commercial trials showed that a combination of delaying fruit cooling for at least 2 d before transport combined with the use of soft inserts can potentially reduce USB in road-freighted ‘Honey Gold’ fruit. The ideal liner has not yet been found.

1. INCREASING THE PERCENT PACKOUT OF PREMIUM GRADE FRUIT

1.1. Introduction

Typical packouts for 'Honey Gold' are about 50% into premium (top grade) and 50% class 1; ignoring reject fruit). Returns for class 1 are marginal in high volume markets and an increased packout to > 70% premium is required to improve profitability. Premium fruit were priced about 50% more than class 1 at the start of the project, however costs of growing, harvesting, packing and transport to markets are identical for both grades. Increasing packout to 70% will improve dollars back to farm by $2 million/year once all current plantings are in full production.

Mango fruit are downgraded at two stages (i) at the packing shed and then (ii) at the market. Possible causes of pre-harvest downgrades include:

- Wind rub from branches and dead flower panicles, due mainly to poor pruning and tree structure
- Poor nutrition
- Russetting possibly from thrip damage at flowering/fruit set
- Powdery mildew at flowering and fruit set, which can also cause russetting
- Cuts from harvesting equipment (picking poles, harvest aids)
- Staining from various causes such as sooty blotch, anthracnose, or other diseases (some fungal causes not yet fully identified)
- Scale and other insect damage
- Lumps on the fruit (pollination issues such as low boron and/or low temperatures)
- Lenticel discolouration (various causes)
- Other unknown causes

Work from the previous project MG06022 has seen fruit downgrades from scale and disease considerably reduced due to better orchard management. However skin markings from other causes are now more evident.

Analysing the types of defects causing fruit to be downgraded to class 1 and reject grade ("downgrade analysis") can identify reasons for downgrade and practices that need to be improved to increase packout percentage. This analysis is not commonly done. A simple sampling procedure, recording system with a quality assessment manual to ensure accurate diagnosis, and good results analysis will identify factors causing loss of quality and downgrade. Improved production and harvesting practices can then be implemented and the success of these practices confirmed by future downgrade analysis. Additional research can be conducted to develop new practices where knowledge gaps exist.

Fruit passing quality assurance inspection at time of packing may exhibit other defects when it finally reaches the market after ripening. Causes could be latent expressions of field diseases; faults in chemical / hot water treatments, transport damage, chilling, and tray insert marks, etc. These fruit need to be formally assessed and rated after ripening at the market to identify areas that growers/packers need to improve upon and will dovetail smoothly with the shed downgrade analysis mentioned above. The process will also allow growers to compare how their fruit performed against a common standard and also to other growers.

1.2. Materials and methods

1.2.1. Downgrades protocol

A reject bin analysis protocol was developed by Hort VC Group, DAFF and Piñata, and circulated to all 'Honey Gold' growers. The protocol provided sampling procedures (number of fruit per harvest date/block), a rating sheet, and procedures for analysing/interpreting the results. Table 2 illustrates the assessment sheet.

1.2.2. Year 1

The five 'Honey Gold' wholesalers and their teams were trained by Piñata and Hort VC Group in the correct identification of mango defects, whether the defects occur pre- or postharvest, the allowances of these defects, and Quality Assurance training in how to appropriately record these defects on 'Honey Gold' fruit sent to them (Table 1). Wholesaler training sessions included defect identification and defect analysis.

Table 1. Downgrades analysis training provided to 'Honey Gold' ripeners and growers

Date	Location	Wholesaler/grower	No. of Attendees
Wholesalers			
24/08/2011	Brisbane	Lind and Sons	18
29/08/2011	Sydney	Express Fruit Service	14
2/09/2011	Melbourne	Flavorite Marketing	12
14/09/2012	Perth	Mercer Mooney	9
15/09/2012	Adelaide	LaManna Group	25
Growers			
14/11/2011	Giru	Burdekin	18
16/11/2011	Mareeba	Mareeba Carnarvon WA	24
6/12/2012	Benaraby	Bundaberg Rockhampton	28

Table 2. Piñata 'Honey Gold' Downgrade Analysis Report

Date: Region Grower

Pre-Harvest Defects	Time:		Time:	
	No.	%	No	%
Soft Nose				
Soft Fruit (Over Ripe)				
Stem End Cavity				
Blemish				
Cleavage Scar				
Pest Damage				
Sapburn				
Pink Spot				
Lenticel Spotting				
Russet				
Sunburn				
Misshapen				
Thin Fruit (immature)				
Dark Green Skin				
Too Small				
Total Pre-Harvest Defects				

Post-Harvest Defects

	No.	%	No	%
Rots				
Wounds				
Sapburn				
Skin Browning				
Abrasion				
Stem Puncture				
Scratches/Cuts				
Pressure Mark/Crease				
Lenticel Spotting				
Brush Damage				
Total Post-Harvest Defects				
Overgrading				
Total Count		**100%**		**100%**

Comments:

QC Name:

Training for farmers was conducted at three locations by Hort VC, Pinata, and THC (Table 1). The first session of the training was based on the same agenda as the wholesaler training - focusing on correct defect identification and allowance levels in 'Honey Gold' specifications. There was also extensive QA training. The second part of the training focussed on showing growers the newly developed "Downgrade Analysis" protocol. This is where growers were encouraged to look at downgraded fruit (i.e. juice bin or reject bin) and assess 50 pieces of fruit to determine the main causes why that fruit was downgraded, and whether the fruit had been over- or under-graded. It was explained to the growers that by doing this a minimum of twice during any day of packing, they would be able to have an extensive set of data at the end of their packing that could be analysed to work out the main defects occurring in their 'Honey Gold' fruit. Appropriate practices could then be implemented to help eliminate these issues in future seasons.

Growers were supplied with a "Downgrade Analysis" form to conduct their analysis. Growers were also supplied with the DEEDI Mango Quality Assessment Manual (Holmes, *et. al*. 2010) which has photographs showing various field defects with descriptions and possible causes.

1.2.3. Years 2 and 3

Pinata and THC provided refresher grower training with one-on-one farm discussions in year 2 (12/13) and year 3 (13/14). Participating growers sent downgrade analysis results direct to Pinata for collation and analysis. This included determining which growers had lower % packout and what distinguishes their growing/management from those growers with higher packouts.

THC over the course of the project frequently visited most farms to provide ongoing extension and training to growers in implementing improved production practices to reduce loss of quality. Additional input was supplied as needed from both Pinata and DAFF.

1.3. Results and Discussion

1.3.1. 2011/12 Year 1

Grower uptake was very low in year 1 as in many instances harvesting had already commenced before training was conducted. Most growers also felt the procedure too time consuming at the busy time of year or did not want to write figures down on paper and then transfer them to computer at night after a long day's work. Data from the main grower who completed the forms was collated and analysed by Piñata and Tropical Horticulture Consulting (Table 3). These data were then presented to the grower, including recommendations on how their crop could be improved in future seasons. Frequent visits from THC helped reinforce this. The example was used at the Annual 'Honey Gold' Congress to stress to others the value of downgrade analysis.

Table 3. Major causes of 'Honey Gold' downgrade in 2011/12

Farm	Region	Defects %		Most common causes for downgrade	Comments/Actions
		Pre-harvest	Postharvest		
A & D. Zugno	Mutchilba Qld	90	9	Fruit too big 35%; Blemish 15%; Fruit too small 12%	6 analyses. At time of harvest, market did not want large fruit. Immature fruit from a second flowering caused small fruit.

1.3.2. 2012/13 Year 2

An improved take up occurred with seven of the largest farms providing results. Major causes of downgrades are listed in Table 4.

Many growers implemented improved practices after seeing their results. For example, Williams prior to harvest appointed a manager specific for mangos, then after harvest had a major rebuild of their orchard sprayer after a HG field day using dyes showed the sprayer was not doing its job giving poor coverage. To help reduce fruit blemish from scratching, a major internal tree pruning occurred following and in addition to the normal pruning. The owners also implemented a fertiliser plan devised by THC in place of previous low input ad hoc programme. Weak areas in the orchard were selectively given top up nutrients as needed. Paclobutrazol growth regulator was used in the correct manner and timing. The 2013-4 crop saw major improvement in crop volume and quality**.**

A and D Zugno's in Mutchilba Qld felt that many of their blemishes were from insects/thrips at flowering or early fruit development. More emphasis was placed on insecticides at this critical time; this type of blemish was reduced in 2013/14.

Walter and Ann Marie's farm had a lot of stem end cavity which normally is associated with lack of calcium. THC did soil and leaf analysis and discussed with the grower his fertiliser programme. He had not applied gypsum (calcium) for many years believing it ineffective. THC devised a fertiliser plan which included both spread and liquid gypsum. Stem end cavity ceased to be an issue in 2013/14.

Table 4. Major causes of 'Honey Gold' downgrade in 2012/13

Farm	Region	Defects %		Most common causes for downgrade	Comments/Actions
		Pre-harvest	Postharvest		
Pinata Fox Road, Block 8	Katherine NT	75	25	Blemish 31%; Sunburn/misshapen 27%; Sap burn pre-harvest 20%	Rows face wrong direction hence more sunburn/misshapen fruit. Cannot change row direction at this stage. Planting error
Pinata Fox Road, Block 6	Katherine NT	82	18	Sunburn/misshapen 42%; Blemish 14%	Trees open and exposed on W side – more sunburn. More growth encouraged after harvest – more fertiliser
Seven Fields	Katherine NT	63	37	Blemish 26%; Sunburn/misshapen 17%; Over ripe 11%; Postharvest sapburn 13%	Tree not managed as well as desired. Block removed
Deans	Katherine NT	88	12	Over ripe 20%; Too small 17%; Lenticel spotting 14%	Too small from second flowering. Took too long to harvest – hence over ripe fruit
Williams	Bowen Qld	95	1	Blemish 57%; Russet 11% Misshapen/lumpy 9%	15 analyses!!Appointed mango manager; rebuilt sprayer following demonstration of poor spray pattern; implemented fertiliser plan; major pruning programme
A & D Zugno	Mutchilba Qld	72	25	Blemish 31%; Pre-harvest sapburn 21% Postharvest sapburn 10%	4 analyses. Increased insecticide sprays at flowering/fruit set
W & A Zugno	Mutchilba Qld	122*	22	Stem end cavity 78% Blemish 35% Postharvest scratches/cuts 14%	3 analyses. Stem end cavity more likely due to low Calcium – has applied gypsum and changed fertiliser programme
Wilbi	Mareeba Qld	68	31	Lenticel pre-harvest 16%; Blemish 15%;	6 analyses. Now using on all cultivars

*Grower got figures mixed up

Regional comparisons are given in Table 5 In 2012/3 blemishes were an issue in all areas, whilst sunburn/misshapen fruit were a major issue in Katherine. (Sunburn can either cause a blackening or deformed misshapen fruit where the sun exposed side does not develop.) A significant number of small fruit were detected in Katherine. This was caused by a second late flowering, where the late set fruit matured at the same time as the initial flowering but due to competition with the first crop and a shorter growing time, these fruit were small at maturity. Most defects seen were pre-harvest. However, some postharvest issues were seen, the level of which varied from farm to farm.

Table 5 Regional comparisons of 2012-13 pre-harvest defects

Defect	**% of defects**		
	Katherine*	**Burdekin**	**Mareeba**
Soft Nose	0.9	1.9	1.5
Soft/over ripe	12	0	5.2
Stem end cavity	1.7	0	3.4
Blemish	15.4	52.5	19.5
Cleavage scar	0	0	1.1
Pest damage	0.3	4.6	3.9
Sapburn	10.6	2	6.3
Pink Spot	0	1.1	1.6
Lenticel spotting	6.9	1.3	8.4
Russet	0.3	10.3	1.1
Sunburn/misshapen	28.6	9.4	7.6
Thin fruit (immature)	0.6	1.4	0
Dark Green skin	2	0.1	0.5
Too small	44.9	2.5	3.1
Too big	0	0	0

***Katherine scored all defects not just the major defect on each fruit – thus more than 100%

The major issue of Katherine fruit i.e. underskin browning (USB) does not show up in the on farm downgrade analysis because the disorder does not become evident until fruit have been stored for at least 4 d and partly ripened.

Table 6 indicates major regional and farm differences in the percentage packouts. Katherine figures were dragged down by a significant number of small fruit (most of which should have been left in the field). Katherine should consistently have the best quality fruit due to its dry climate during the fruit development phase and SE Queensland farms (Wamuran and Bundaberg) normally would expect lower % premium due to more adverse weather and longer time the fruit are on the tree.

In Rockhampton the major farm had a lot of bumpy fruit caused by low temperatures at flowering which downgraded the whole crop. In Bundaberg one grower has major issues which could have easily been avoided.

Table 6 2012-13 Average regional percentage packouts for 'Honey Gold' growers across the major production areas.

Region	% Premium	% Class 1	% Bulk/Juice	Range in % Premiums
Katherine	44.1	33.2	22.7	37-55
Burdekin	52.9	34.5	12.6	39-55
Mareeba	63.1	29.6	7.3	48-74
Rockhampton	36.6	36.5	26.9	1-65
Carnarvon	45.4	36.9	17.7	43-58
Bundaberg	53.2	25.7	20.6	0-66
Wamuran	6.9	31.3	61.8	5-21
Objective	>60	30	10	

1.3.3. 2013/14 Year 3

A similar number of growers, comprising the majority of 'Honey Gold' production, completed downgrades analysis in year 3 (Table 7). Normally there would have been a large number of analyses from the NT, but the 2013/14 crop was very light. Methods of recording downgrades were different from Pinata farms thus comparisons of % breakdown are complicated.

Table 7 Major causes of 'Honey Gold' downgrade in 2013/4

Farm	Region	Defects %		Most common causes for downgrade	Comments
		Pre-harvest	Postharvest		
Williams	Bowen Qld	93	1	Blemish 40%; Pink Spot 16% Sunburn 11%	Pink spot and sunburn varied with samples. Blemish consistent over all samples 13 analysis taken
A & D Zugno	Mutchilba Qld	78	21	Blemish 33%; Pre-harvest sapburn 19% Postharvest sapburn 13% Over ripe fruit 9%	11 analyses taken. Fruit spotting bug damage in some blocks. Over ripe fruit an issue as time went on. Had to harvest other cultivars first
Wilbi	Mareeba Qld	81	16	Blemish 36%; Lenticel pre-harvest 20%;	9 analyses. Fruit staining and sooty mould also serious issues
Pinata*	Rockhampton	68	32	Sunburn and blemish pre-harvest. Rots, wounds, cuts/scratches postharvest	8 Analyses
Pinata Easton*	Wamuran Qld	86	14	Sunburn, blemish and overripe fruit main pre-harvest. Wounds and cuts/scratches postharvest	10 analyses. Harvest stretched out, thus over ripe fruit
Pinata*	Wamuran, Q	85	15	Sunburn and blemish pre-harvest, wounds and scratches/cuts postharvest	16 Analyses
Pinata	Katherine, NT	75	25	Sunburn pre-harvest and rots postharvest	

*All packed and assessed at same shed

Pre-harvest defects were again more common than postharvest defects. Blemish was again the most common downgrade but more detailed defects descriptions are required to better identify remedial actions as many factors that can result in blemished fruit.

Williams' farm suffered from pink spot (caused by scale infestation). Scale control was good until harvest then a late outbreak occurred because chemical withholding periods prevented the use of effective sprays during harvest. Pink spot incidence increased as the harvest progressed because of longer times from the last effective spray.

Zugno's farm had issues with both pre and postharvest sapburn. Pre-harvest sap burn was due to adjacent fruit damaging each other. The farm also had fruit spotting bug damage in one block. The previous chemical that provided excellent control is no longer registered and replacements are less effective. Over-mature fruit was due to the need to harvest other cultivars first. Heat sums predictions showed the fruit could have been harvested much earlier than they were.

Wilbi suffered from lenticel damage in both years 2 and 3. Why this farm suffers more than others is not yet clear. This farm and another Mareeba farm also had sooty blotch and subsequent fruit staining. The blotch forms on the limbs or dead flower panicles and heavy rain washes the stain/fungus onto the fruit; this cannot be removed on the packing line. Control is a combination of better pruning and a spray program.

Pinata farms at Rockhampton, Wamuran, and Easton all suffered sunburn damage as well as blemishes. All had postharvest damage from wounds, cuts and scratches. All farms were harvested with the same harvest equipment and packed at the same shed. Over-ripe fruit was apparent at both Wamuran and Easton. These farms mature at the end of the mango season and there was an attempt to stretch out the harvest to extend the marketing window. Heat sums prediction at Wamuran indicated fruit to be mature before harvest commenced (refer to Table 5)

There was an improved packout this season in most areas and most farms due to better management and especially dry weather conditions. Twelve growers had better than a 60-30-10 packout with two growers having >70% Premiums.

1.3.4. Three year results

Table 8 illustrates variability between regions and from year to year. Bundaberg showed a large decrease in % premiums in 2013/14 as one farm failed completely due to poor management. This same property also grows a large number of 'Calypso' and KPs which also failed. This farm thus dragged down the pooled results. The other large 'Honey Gold'/'Calypso' farm had good packouts. A similar situation occurred in Carnarvon where one farm had one of the best overall packouts but the other large farm suffered from adverse weather conditions downgrading many of the fruit.

Mareeba had some of the best individual packout percentages but in 2013/14, two farms suffered from heavy pre harvest rain which caused fruit staining and lenticel damage. Fruit were downgraded on these farms which then dragged down the area average.

Table 8 Three year regional packout percentages

		2013/14	2012/13	2011/12
Bundaberg	Premium	38.04	53.35	58.76
	Class 1	37.63	25.56	25.61
	Class 2 (bulk)	24.32	21.09	15.63
Burdekin	Premium	55.70	52.92	57.59
	Class 1	33.20	34.53	38.35
	Class 2 (bulk)	11.10	12.55	4.06
Carnarvon	Premium	44.50	45.38	53.23
	Class 1	37.41	36.87	21.23
	Class 2 (bulk)	18.09	17.75	25.54
Katherine	Premium	76.22	45.1	47.41
	Class 1	17.91	34.00	52.59
	Class 2 (bulk)	5.87	20.90	0.00
Lismore	Premium	57.48	26.43	46.43
	Class 1	42.52	40.02	53.57
	Class 2 (bulk)	0.00	33.56	0.00
Mareeba	Premium	53.91	63.29	65.58
	Class 1	35.04	29.22	28.85
	Class 2 (bulk)	11.05	7.5	5.58
Rockhampton	Premium	58.21	31.63	38.15
	Class 1	27.55	35.92	34.38
	Class 2 (bulk)	14.24	32.45	27.47
Wamuran	Premium	33.96	6.83	17.33
	Class 1	20.78	31.03	14.44
	Class 2 (bulk)	45.27	62.14	68.22

In contrast the main farm in Rockhampton had minimal premiums in 2012/13 due to cold winter conditions leading to bumpy fruit, however in 2013/14 winter conditions were more favourable and there were no downgrades due to bumpy fruit.

Wamuran in SE Queensland has harsh growing conditions with most years having many rain events during fruit development leading to poor packout. In 2013/14 drier weather conditions, improved pruning and spraying led to a much better packout. This area as mentioned earlier will always struggle to achieve high quality fruit.

The price differential between premium and class one fruit has narrowed considerably, dropping from $7.17 in 2011/12 to $5 in 2012/13 to $3.27 in 2013/14. This is the direct result of Project MG10009 by improving the consistency of grading between farms coupled with a strong marketing effort to find new markets for non-premium fruit. Class 1 fruit are now being marketed in one of the major chains and also sent direct to New Zealand.

1.4. Summary and recommendations

Adoption of downgrades analysis was slow but improved in later years, but further illustration of its benefits is required to encourage more growers to participate.

Better standardisation is required in defects identification and recording across farms and ripeners because inaccurate identification results in recommendation of inappropriate control measures and difficulty on collating the results and comparing between farms. Methods of recording and transferring data to and from Pinata need to be improved and simplified. Pinata also needs to have a rapid turnaround to growers of analysed data so they can respond to results and recommendations as soon as possible. Additional training is required.

The original pack out objective was >70% premiums and 30% class 1. However this did not include the juice/bulk grade fruit. In a practical commercial basis they must be included as they are part of the yield and fruit which hopefully finds a market. A commercially realistic packout is 60% premium, 30% class 1, and 10 % bulks/juice (60-30-10). This has been achieved on several farms. However for several reasons, a number of farms had less than 50% premiums.

The wide range in % premiums between farms and regions indicates considerable room for improvement in profitability. Some wetter areas will struggle to consistently achieve 60% premiums but this can be improved. Improvements have been made on several farms by the hard work of the owners. In other instances growers have lack the finances and/or labour to improve practices. This is especially an issue on smaller properties.

The gap in pricing between Premiums and Class 1 fruit has narrowed considerably during the 3 years of MG10009 due to more consistent packhouse grading and marketing efforts to find markets for non premium fruit.

THC has been providing on-going extension and training to growers in improved production practices to reduce loss of quality and improve packout ratios and profitability. Many of the solutions are not difficult but are generally common sense issues which growers need more encouragement to implement. In other instances growers had forgotten to undertake basic practices.

2. CROP FORECASTING

2.1. Introduction

A crop forecasting model based on climatic data would help 'Honey Gold' growers determine optimal maturity as well as giving markets a better understanding of when they may expect fruit. The model could also potentially identify areas where mangoes can be grown to fill gaps in the market.

Moncur *et. al.* (1984) made an early attempt to model this where 'Kensington Pride' mango could be grown in Australia using accumulated degree hours above 16°C with an upper limit of 35°C, settling on 22,000 degree hours between 16 and 35°C. Diczbalis *et. al.* (1997) used accumulated heat sums to predict fruit maturity. They found this method as good or better maturity predictor than dry matter % at harvest as maturity is related to temperature.

More recently the NT Government (2009), following earlier work of Diczbalis *et. al.* (1997) developed a Crop Forecasting Manual using accumulated heat units from the formula:

Heat Sum = ((maximum °C + minimum °C)/2) - 12°C

12°C is considered the temperature below which mango growth ceases (Young 1955; Singh *et. al.* 1966). The NT model suggests different mango varieties require slightly different accumulated heat units to reach maturity (Table 9).

Table 9 Recommended accumulated heat units above 12ºC as a minimum maturity standard

Variety	Recommended heat units at maturity
'Kensington Pride'	1600
'Calypso'	1680
'R2E2'	1800
'Honey Gold'	1800
Florida types ('Keitt', 'Kent', 'Hayden', 'Tommy Atkins')	1680

The NT manual states the time to start measuring heat sums varies with variety. 'Kensington Pride' and 'R2E2' should start at early panicle emergence whereas it is suggested that 'Calypso' and 'Honey Gold' should commence when there is a full panicle (approximately 2/3 open flowers) on about 50 % of the flowering terminals. The Calypso Best Practices Manual uses full flower (Stage i in the flowering chart; Plate 1) as the starting date.

To help growers and marketers of 'Honey Gold', work was initiated to develop a suitable heat sum crop forecasting model to be supplemented with dry matter results.

2.2. Materials and methods

2.2.1. Heat sums

In May/June 2011 Tiny Tag data loggers [Ultra 2 Internal Temperature and Tiny Tag Plus with tipping bucket rain gauge] were purchased and installed at eight sites. In 2012 an additional logger was installed at Pinata farm in Rockhampton (CQ). Site details are given in Table 10. The logger sites were used to collect data for the crop forecasting and the USB production factor component of this project.

THC, Piñata, and DAFF felt that it was more logical to use stage i (full flower) rather than the earlier flowering stages suggested in the NT as the starting point for heat sum accumulation. In NT due to hotter temperatures, flowers progress rapidly through the flowering stages. However in cooler environments, flowers can pause for some time at the earlier stages before resuming growth, making the estimate of the starting time more difficult. Hence it was agreed that full flowering (stage i) was a more useful starting tool to use in a wider range of environments.

The dates of when the orchard reached stage i (full bloom) (Bally and Holmes 2002) were recorded by growers and/or THC. Daily heat sums from stage i were determined using the following formula which uses the daily average temperatures until a pivotal heat unit is reached

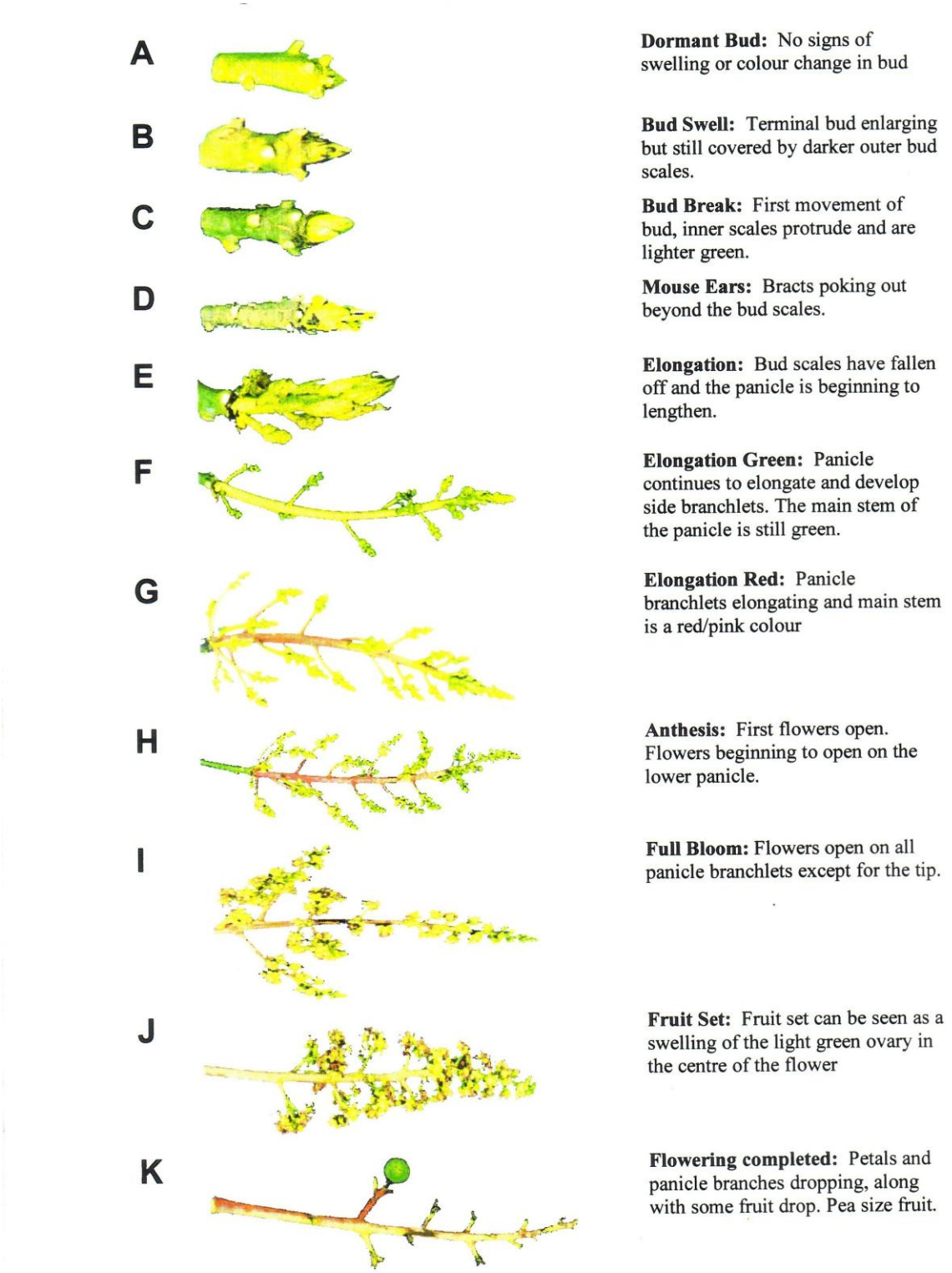
Heat Sum = ((maximum ^{o}C+ minimum ^{o}C)/2) - 12^{o}C

The estimated date of fruit maturity was calculated by THC with the above formula using data from both the data loggers and long term average minimum and maximum temperatures recorded by the nearest Bureau of Meteorology data station. Heat sum predictions were also done for a number of other locations as part of the project but this report will concentrate on those with data loggers and a fuller set of information. Heat sums were also used to rule out several potential sites where it was felt 'Honey Gold' could be grown to fill gaps in production timing.

Table 10 Farms where temperature and rainfall loggers were installed to collect heat sum and rainfall data.

Grower	**Location**
Pinata Fox Road	Katherine, NT
Peter Deans	Katherine, NT
Pinata Mataranka	Mataranka, NT
Maurice Cetinic	Mareeba, FNQ
Adrian Zugno	Mutchilba, FNQ
Lionel Williams	Bowen, NQ
Pinata Rockhampton	Rockhampton, CQ
Tom Gorton	Outside Bundaberg, SQ
Pinata Wamuran	Wamuran, SEQ

Plate 1 Flowering stages used to describe when heat units start relative to the flowering stage for each variety (Bally and Homes 2002)



2.2.2. Dry Matters

Ten trees of similar stature were marked at each of the data logger sites; these trees were used to obtain fruit for dry matter determination. To determine the percentage dry matter, 6-10 average fruit were collected at each site and sent by Express Post to Wamuran where dry matters were determined. The objective was to harvest fruit at 1.5 and 3 weeks pre-harvest and at harvest, however, the number and timing of samples varied.

In year 3, NT samples were done at Pinata farm in Katherine. Bowen samples were done by the grower using the same equipment and methodology used by Pinata. It was planned that Mareeba samples would be done at Piñata's pineapple farm in Mareeba but samples were instead posted to Wamuran.

For each fruit a section was taken from each cheek and grated or diced. In Year 3 an apple corer was used to take samples based on the method of Moore and Owen (2013). Samples were dehydrated using an Ezidri D09H Food dehydrator at 60°C until fruit weights did not drop any further. A Bristol #20 paint colour reference chart was used to compare flesh colour in year 1.

2.3. Results and Discussion

2.3.1. Heat Sums

2.3.1.1. Stage i and time of maturity

Despite differences in dates of stage i, time of harvest over the years was consistent at most sites (Table 11). Cetinic in Mareeba was an exception as he had a very early flowering and harvest in 2011 but returned to a more normal harvest time in years 2 and 3 of the project.

2.3.1.2. Heat sums in different regions

Comparisons of three growing regions (Figure 1) shows the NT (Katherine and Mataranka) had a higher heat sum accumulation pattern than SEQ (Bundaberg and Wamuran) or NQ (Mareeba, Mutchilba and Bowen). This is to be expected as harvest dates are first in NT and last in SE Queensland with NQ in between. Northern Territory had higher average daily temperatures than the other regions.

Table 11 Dates of stage i, start of commercial harvest and accumulated heat units at the start of commercial harvest at the farms sites were temperature loggers were located (the logger sites).

Grower Location	**Year**	**Date stage i**	**Date harvest**	**Heat units at start of commercial harvest**
Piñata	2011	23 Jul	20 Nov	1746
Katherine	2012	30 Jul	19 Nov	1744
	2013	1 Aug	14 Nov	1726
Deans	2011	20 Jun	15 Nov	1916
Katherine	2012	15 Jul	12 Nov	1621
	2013	10 Aug	14 Nov	1630
Pinata	2011	17 Jul	25 Nov	1755
Mataranka	2012	1 Aug	26 Nov	1670
	2013	15 Sept	5 Dec	1494
Cetinic	2011	26 Jun	12 Dec	1540
Mareeba	2012	17 Sept	4 Jan	1338
	2013	26 Aug	6 Jan	1603
Zugno	2011	12 Jul	30 Dec	1863
Mutchilba	2012	30 Jul	2 Jan	1841
	2013	18 Aug	6 Jan	1765
Williams	2011	28 Jul	28 Dec	1720
Bowen	2012	1 Aug	20 Dec	1411
	2013	5 Aug	16 Dec	1483
Pinata	2011			
Rockhampton	2012	10 Aug	5 Jan	1550
	2013	30 Aug	7 Jan	1688
Gorton	2011	19 Aug	23 Jan	1647
Bundaberg	2012	4 Oct	31 Jan	1392
	2013	19 Aug	11 Jan	1639 (BOM data)
Pinata	2011	2 Sept	27 Feb	1814
Wamuran	2012	10 Sept	12 Feb	1699
	2013	19 Aug	5 Feb	1775

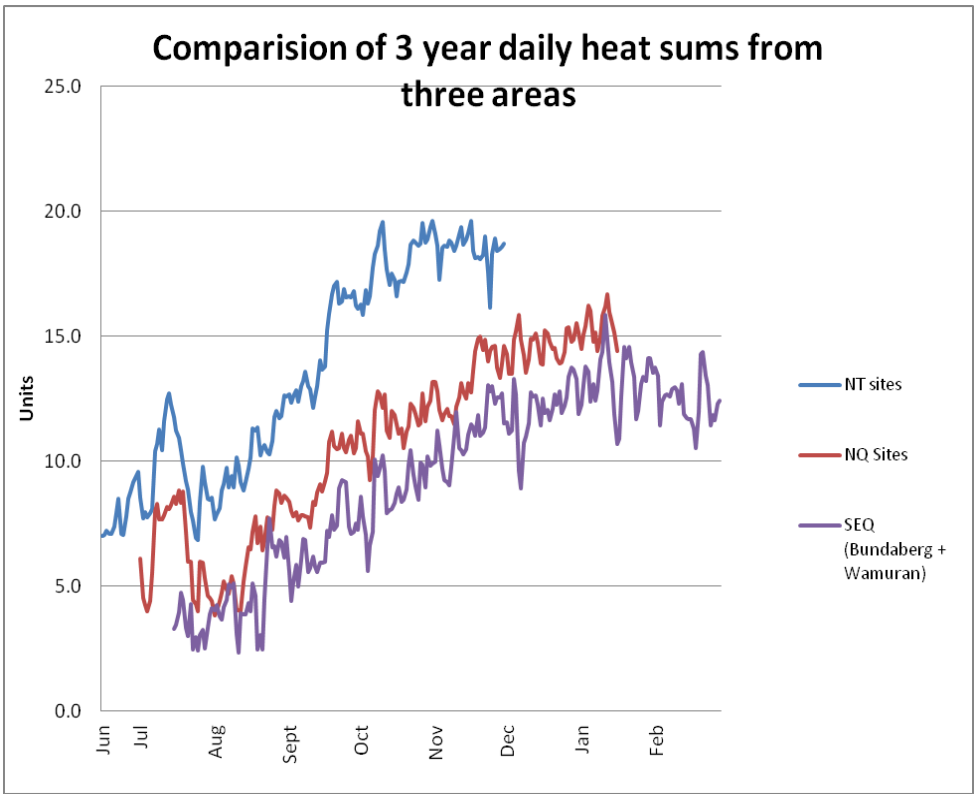


Figure 1 Comparison of mean daily heat units (2011-2013) in three main growing regions from flowering until harvest.

Northern Territory

Differences between locations with heat sum accumulation are minimal when the three Katherine and Mataranka locations are compared with that of the Tindal BOM over the same three year period. Tindal is very close to the Fox Road farm whilst Mataranka is approximately 100 km south. Mataranka heat units are minimally lower than those of the Katherine sites of Deans and Fox Road; however, this is important commercially as a slightly later harvest timing for Mataranka is highly desired.

Originally it was felt that Mataranka would mature two weeks or more after Katherine, thus spreading harvest. In reality, it is mainly management interventions (such as delaying/advancing flowering, water management to advance/delay maturity, and delaying the start of harvest that have the greatest influence on the degree of harvest overlap between Mataranka and Katherine.

A comparison of the last three years means of the farms with the long term Tindal average (1985-2013) shows that the last three years were generally cooler than average. However winter 2013 was hotter than the long term average resulting in most NT farms having a very poor extended flowering irrespective of cultivar.

Tindal BOM data could safely be used to predict heat sums and anticipated harvest dates for the NT sites. However due to the need to have fruit as early as possible and to delay Mataranka until Katherine sites are harvested, it is strongly recommended to maintain data loggers at all sites for

heat sum predictions. In the Katherine/Mataranka situation, a few days difference in timing of harvest can make a large commercial difference.

Far North and North Queensland

When the two Far North Queensland sites (Zugno in Mutchilba and Cetinic in Mareeba) are compared with that of Williams in Bowen, all follow the same pattern of heat unit accumulation. Bowen is more than 600 km south of the FNQ sites. Cetinic is nearer the coastal ranges west of Cairns but Zugno is further inland. Rockhampton in Central Queensland also follows a similar pattern.

Zugno in Mutchilba accumulates more daily heat units than Cetinic with the Bowen site in between (Figure 2). Cetinic has a lot of showery and hence cloudy days that Zugno does not.

In comparing sites over the three years, Zugno (some 20 km from the Mareeba airport) is slightly warmer than the airport and data from the airport is less reliable for this site but surprisingly Williams in Bowen (some 600 km south) seems a reasonable match. However, there is no long term data for Williams farm. Cetinic is slightly cooler than the airport.

Mareeba airport could give a guide for the far north sites but local differences traditionally show up to 10-14 days difference in time of harvest between different microclimates, elevation, and soil types. The area has two main soil types – granitic sandy loam and a volcanic krazonzam. Closeness to the coastal range as well as elevation also influence time of maturity. It is recommended that two data loggers be maintained – one at Cetinic to service Mareeba farms, and one at Zugno to service Mutchilba and Dimbulah.

There is no long term data for the Bowen farm which is inland from Bowen and next to a small range of hills. Due to the number of trees present and being planted as well as the time of fruit maturity (after Mataranka but just before Mutchilba), a data logger should be maintained to help predict fruit maturity.

Heat sum accumulation data from Ayr Research Station is a good indicator for the ‘Honey Gold’ farm in Giru (data not presented).

Central Queensland

Piñata’s farm inland from Rockhampton is the only CQ farm with a data logger, which was installed in year 2. When figures from the past two years are compared, the farm accumulates fewer daily heat units than Rockhampton airport (Figure 3). A logger should be maintained at this farm for several more years to get a good comparison with Rockhampton airport.

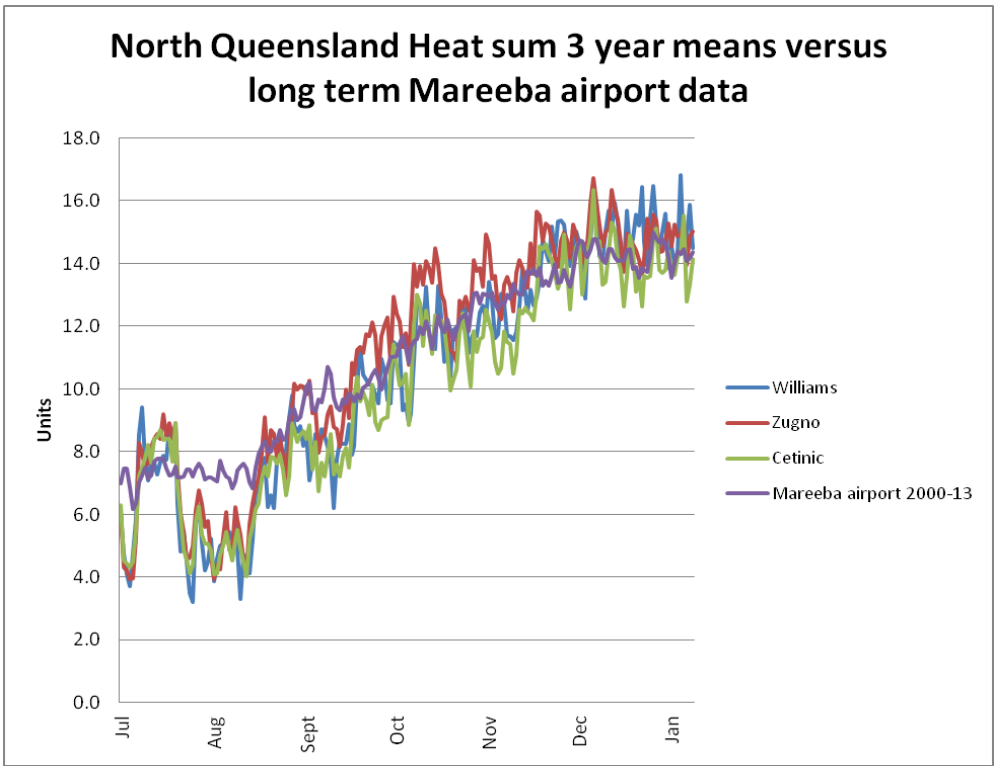


Figure 2 Comparison of North Queensland 3 year heat sums and long term Mareeba airport data

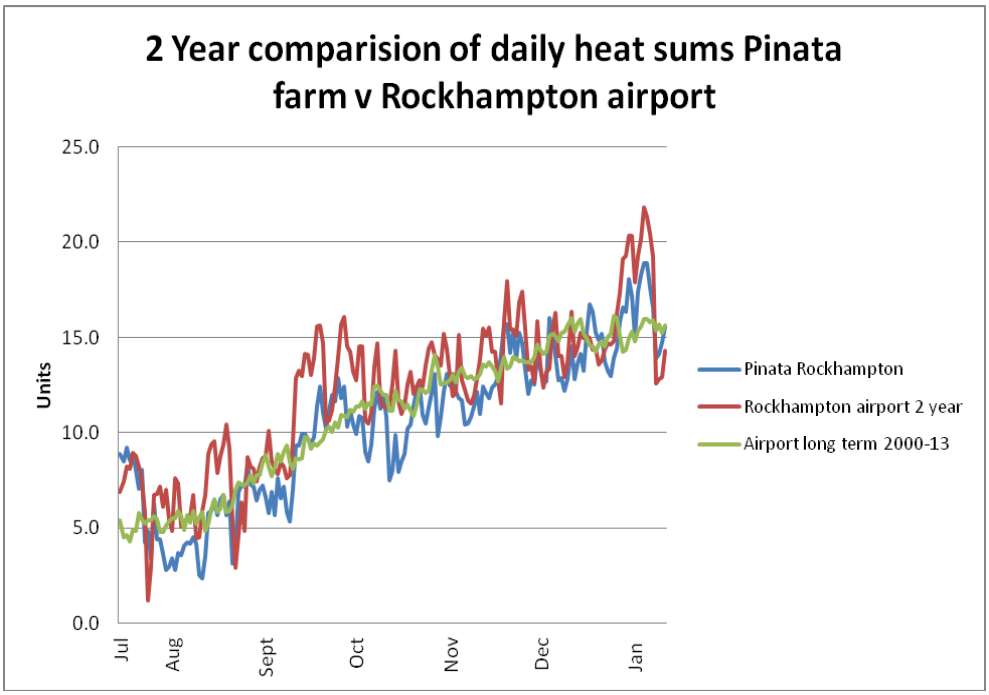


Figure 3 Central Queensland comparison of Piñata farm versus Rockhampton airport BOM data.

'Honey Gold' are also grown at Yeppoon east of Rochampton nearer the coast. The climate there is milder and much wetter than Rockhampton airport and the Piñata farm . Fruit matures after Rockhampton. The most suitable site for heat sums determination is the Samual Hill BOM station. It is not fully accurate but more accurate than Rockhampton airport (data not presented).

There are three 'Honey Gold' farms 1-2 hours south of Rockhampton at Beneraby and Yarwin. The nearest BOM station is Gladstone on the coast, but is not relevant as the farms are more inland. Likewise the climate is different than Rockhampton and fruit matures after Rockhampton. Due to the large number of 'Honey Gold' trees grown in this area, especially in two adjacent farms, installation of a data logger would be useful to build up a set of data for maturity predictions.

Bundaberg

The Gorton's farm is some 40 miles from Bundaberg airport and is more coastal. There was a loss of meterological date in 2013 as the data logger was not cleared. Accessing this farm is always a issue as it not close to any MG10009 personnel. However the farm does have a large number of both 'Honey Gold' and 'Calypso' trees. THC will attempt to train office staff at the farm to download the logger data on time.

Gorton's site is slightly cooler than the Bundaberg airport. However the airport data was able to predict harvest date of another inland farm closer to the airport where there is no logger (data not presented).

Wamuran

Wamuran is the most southern of the nine data logger sites and the last site to harvest fruit in the season.

2.3.1.3. Optimal Heat sum for maturity prediction

Based on 'Honey Gold' fruit maturity observations it was decided in year 1 that 1500-1600 accumulated heat units was sufficient for fruit to reach commercial maturity. This has now been refined to 1500 units. This conclusion was based on experience and several factors:

- *Time of maturity* – 'Honey Gold' is generally ready to harvest about two weeks after 'Kensington Pride'. Fruit starting to ripen on the tree and drop means time to commercial harvest is near.
- *External fruit characteristics* – 'Honey Gold' develops a fullness around the shoulder and at the nose. There is a definite rising of the shoulders above the stem point of attachment when fruit is mature.
- *Internal fruit colour* – internal flesh changes from white to pale yellow.
- *Dry Matter* – Previous work initially suggested 16% dry matter as the standard (Hofman and Stubbings (2013). However this was done in one season and one locaton only. Detailed maturity work with 'B74' indicated a minumim DM of 14%, although there were seasonal and regional variations. Hence 15% dry matter was considered acceptable.

Fruit that had reached 1500-1600 units met the above critera for maturity. Fruit at 1400 units were felt too marginal although many would have passed the DM maturity standard. When fruit

were >1700 heat units fruit drop was occurring. Thus 1500 accumulated heat units was considered the most appropriate target.

NT work suggested 1800 heat units for 'Honey Gold' based on a heat sums start of early panicle emergence (Owen and Moore 2009). Recently, others wanted to start all cultivars at Stage d on the flowering chart. In the present work, stage i or full flower was the starting point. There is approximately 250 heat unit difference between between stage d and stage i in the NT (Ian Baker pers. Comm.). Thus a figure of 1550 units would be the standard by this method which corresponds closely with the decision to use 1500 units using stage i as the earliest harvest.

2.3.1.4. Projected harvest times

With data gathered in 2011, efforts were made to predict time of maturity in 2012 and 2013 using both data logger temperatures and long term data from the nearest suitable BOM station. Heat sum predictions in most instances were close to when logger fruit were mature. In a number of instances commercial harvests were a few days later (Table 12) as explained in the table. NT figures were particularly relevant where growers are chasing the early market and a few days difference is important for both harvesting and marketing.

Heat sum forecasting becomes more accurate with more years of data. Trial sites close to BOM stations had accesses to more than 25 years of temperature data. Accuracy was particularly good in Katherine as the Fox Road farm is located very close to Tindal BOM. In a site like William's in Bowen, temperatures at the site are different than the nearest BOM station thus there was less reliable data to work with initially. In many instances THC was able to compare logger data with BOM for crop harvest predictions. In most instances a combination of logger current heat sums combined with long term BOM readings gave the best results. As more data was gathered, using only averages from loggers alone gave good results.

It should be stressed anticipated dates of harvest are for the trees around the data loggers – this may not apply uniformly to the whole farm where flowering may have been at a different time with a different microclimate, etc. Loggers were not necessarily installed in the earliest part of orchard (often unrealised at start of project) but where convenient and less likely to get knocked over by machinery.

Three years of work has shown that a heat sum of 1500 units provides a good guide to when 'Honey Gold' are likely to be commercially ready for harvest. Use of heat sums removes variables which can make other methods of maturity prediction less useful. However growers still need to evaluate fruit externally and internally before making the critical decision on when to harvest.

2.3.2. Dry Matters

Dry matter percentages were determined at several dates at each data logger site (Table 13). No samples were taken at harvest at Wamuran and Williams in 2011/2 as the test plots were accidently harvested. Results were disappointing and in general did not relate well to heat sums or physical indicators of maturity. Williams' results in all three years both analysed at Wamuran and by the grower bare no relevance to reality of maturity. In the first two years sending fruit by

Express Post bags often took four days to reach Wamuran resulting in fruit sweating in the bags and inaccurate results.

The dry matter maturity test needs to be done accurately and consistently to get meaningful results, and ideally the results should be compared with eating quality to determine the minimum maturity standard. Disciplined taste panel assessments were outside the resources of this project, and the dry matter experience indicated the challenges of having the samples analysed properly. Hence, overall heat units were considered a more appropriate commercial measure to predict the start of harvest.

In year 1, the fruit used for dry matter testing were evaluated using a colour chart (data not presented). There was a good relationship between flesh colour and dry matter. However the method was discontinued in year 2 due to inconsistencies in the methods and the time involved.

Table 12. Projected and actual commercial harvest dates using data logger trees

Grower/location	Year	Projected Harvest 1500-1600 heat units	Actual harvest date	Heat units at harvest	Comments
Pinata Fox Road NT	2012/3	6-11 Nov	19 Nov	1744	Could have harvested a few days earlier, drops
	2013/4	5-10 Nov	14 Nov	1726	More than one flowering delayed harvest
Deans NT	2012/3	5-9 Nov	12 Nov	1621	Logger in coldest part of farm. Could have picked a few days earlier
	2013/4	9-14 Nov	14 Nov	1630	About right with dates. Very light crop
Mataranka NT	2012/3	18-25 Nov	26 Nov	1670	Pretty ripe, rain delays and trying to stretch out harvest
	2013/4		5 Dec	1494	Very limited flowering
Cetinic FNQ	2012/3	15-22 Jan	4 Jan	1338	Late flowering, could have stayed on tree longer
	2013/4	25 Dec	6 Jan	1603	About right
Zugno FNQ	2012/3	12-20 Dec	2 Jan	1841	Needed to harvest KP and R2E2 first
	2013/4	19-25 Dec	6 Jan	1865	Could have done some earlier, picked other cultivars first
Williams NQ	2012/3	18-25 Dec	20 Dec	1411	Could have waited a week but a lot of trees to harvest
	2013/4	22-27 Dec	16 Dec	1483	Large crop, rush to start
Rockhampton CQ	2012/3	25 Dec	5 Jan	1550	Got about right. Delay over Xmas
	2013/4	29 Dec-5 Jan	7 Jan	1688	About right
Gorton SEQ	2012/3	3-10 Feb	31 Jan	1392	
	2013/4	8-14 Jan	11 Jan	1639	About right
Wamuran SEQ	2012/3	7-14 Feb	12 Feb	1699	Got it about right
	2013/4	23-30 Jan	5 Feb	1775	Could have picked earlier but trying to stretch out

Table 13 The 'Honey Gold' dry matter (%) accumulated heat sum results from the logger sites. The dates in bold indicate the start of commercial harvest.

Grower	**2011/2**			**2012/3**			**2013/4**		
	Sample date	**% Dry Matter**	**Heat sums**	**Sample date**	**% Dry Matter**	**Heat sums**	**Sample date**	**% Dry Matter**	**Heat sums**
Pinata Katherine	18 Oct	13.52	1163	16 Oct	13.73	1103	24 Oct	14.2	1315
	1 Nov	14.86	1413	25 Oct	16.5	1267	29 Oct	16.2	1412
	7 Nov	16.06	1516	9 Nov	16.7	1554	**14 Nov**	**17.11**	**1726**
	20 Nov	**16.69**	**1746**	**19 Nov**	**16.7**	**1744**			
Deans Katherine	18 Oct	12.28	1406	16 Oct	13.75	1141	23 Oct	15.11	1093
	1 Nov	13.76	1663	25 Oct	15.42	1306	29 Oct	17.82	1310
	7 Nov	14.92	1769	**12 Nov**	**18.08**	**1621**	6 Nov	18.33	1491
	15 Nov	**17.65**	**1916**				**14 Nov**	**17.94**	**1630**
Pinata Mataranka	18 Oct	12.59	1103	8 Nov	14.45	1322	21 Nov	18.73	1247
	31 Oct	14.62	1325	19 Nov	15.64	1526	**5 Dec**	**Lost**	**1494**
	7 Nov	15.48	1442	**27 Nov**	**Lost**	**1670**			
	25 Nov	**16.6**	**1755**						
Cetinic Mareeba	9 Nov	11.78	1089	13 Dec	13.68	1019	3 Dec	13.1	1136
	1 Dec	13.76	1366	**4 Jan**	**15.5**	**1338**	18 Dec	13.84	1340
	12 Dec	**14.66**	**1540**				**6 Jan**	**16.67**	**1603**
Zugno Mutchilba	15 Nov	12.83	1201	3 Dec	16.37	1373	3 Dec	14.58	1366
	1 Dec	14.15	1423	13 Dec	18.62	1527	18 Dec	16.51	1579
	12 Dec	**16.36**	**1601**	**2 Jan**	**19.56**	**1841**	**6 Jan**	**19.42**	**1865**
	31 Dec*	**16.26**	**1863**						
Williams Bowen	14 Nov	15.2	1054	11 Dec	16.83	1307	20 Nov	17.68	1118
	29 Nov	16.4	1269	**20 Dec**	**17.75**	**1411**	27 Nov	18.13	1252
	12 Dec	18.35	1483				4 Dec	18.34	1318
	28 Dec **		**1720**				**16 Dec**	**17.75**	**1483**
Pinata Rockhampton				22 Dec	16.0	1343	10 Dec	17.21	1237
				29 Dec	17.8	1443		19.37	
				5 Jan	**Lost**	**1550**	7 Jan	**20.32**	1688
Gorton Bundaberg	16 Jan	17.21	1490	8 Jan	14.91	1066	?		
	23 Jan	**16.90**	**1580**	**31 Jan**	**17.44**	**1392**	**11 Jan**	**na**	**na**
Pinata Wamuran	16 Jan	13.17	1286	31 Jan	17.4	1560	9 Jan	14.37	1443
	1 Feb	13.08	1481	**12 Feb**	**17.32**	**1699**	**5 Feb**	**lost**	**1775**
	13 Feb	14.25	1636						
	27 Feb**		**1814**						

*second harvest ** no sample na = not available

2.3.3. Days to 1500 units maturity and to harvest

Days to actual commercial harvest was a poor maturity indicator as too many other factors influence harvest date. For example in the NT, in year 1 Pinata was dependent on outside contractors to harvest the fruit. Pinata had to wait for the contractor to finish harvesting other non 'Honey Gold' farms first. Likewise the packshed packed from its own orchards of 'Kensington Pride' and 'R2E2' before they would start packing 'Honey Gold'. Fruit were ready but Pinata was unable to pick and pack.

Harvest at Mataranka used the same contractor as Katherine, was delayed in part from the need to finish Katherine farms first but also to prevent market over-supply.

In FNQ and NQ, growers also have 'Kensington Pride' and 'R2E2' mangoes, both of which mature slightly earlier than 'Honey Gold'. 'Kensington Pride' and 'R2E2' when mature, quickly start dropping, whilst 'Honey Gold' holds on the tree better, so growers often harvest the former varieties first.

The Wamuran harvest was delayed as long as possible to supply fruit to the market after other areas have finished. In the year 3 some fruit was lost as harvest was probably stretched out too long.

Days to harvest and 1500 heat units varied between years depending mainly on time of flowering. When trees flowered early, it took longer to reach the optimal heat sum (less heat units in winter at the time of flowering). Later flowerings took less time to accumulate the necessary 1500+ heat units.

There was a wide range in days to 1500 heat units at any one location let alone between geographical areas. For example the days to reach 1500 at Fox Road in Katherine ranged from 94 to 107 over the 3 years, whilst at Deans (also Katherine), it was 90 to 124 d. In 2011 Deans had a very early flowering but fruit grew slowly during the cooler winter period thus needing 124 days to reach 1500 heat units. 2013 flowering occurred later than normal after the cooler times had passed and only 90 days were required. Cetinic (Mareeba) ranged from 120-165 d. In the 165 year, early flowering resulted in fruit sitting on the tree throughout the cool winter months, while in the 120 year; flowering was late and occurred in the warmer months.

2.4. Summary and Recommendations

Three years of work has shown a heat sum of 1500 units provides a good guide to when 'Honey Gold' are likely to be commercially ready for harvest. However growers still need to evaluate fruit externally and internally before making the critical decision on when to harvest.

Dry matter results were unreliable most likely because of inconsistent methodology under the time pressures near the start of commercial harvest. Hence dry matter was considered a less suitable predictor when harvest can start. Also, days to 1500 heat units are poor maturity indicators as they vary far too much.

Tindal BOM data could safely be used to predict heat sums and anticipated harvest dates for the NT trial sites. However due to the need to have fruit as early as possible and to delay Mataranka until Katherine sites are harvested, it is strongly recommended to maintain data loggers at all sites for heat sum predictions. In the Katherine/Mataranka situation, a few days difference in timing of harvest can have a large commercial impact.

Mareeba airport could give a rough guide for the FNQ sites but local differences traditionally show up to 10-14 days difference in time of harvest between different microclimates. Closeness to the coastal range as well as elevation influences time of maturity. It is recommended that two data loggers be maintained – one at Cetinic to service Mareeba farms, and one at Zugno to service Mutchilba and Dimbulah.

There is no long term data for the Bowen farm which is inland from Bowen and next to a small range of hills. Due to the number of trees present and being planted as well as the time of fruit maturity (after Mataranka but just before Mutchilba), a data logger should be maintained to help predict fruit maturity. The Piñata Rockhampton farm logger should also be maintained until several more years data is available to compare with the Rockhampton airport. Heat units for Yepoon can be roughly caculated from the Samual Hills BOM

Central Queesnland fruit in the Beneraby and Yarwin areas lack a suitable BOM station. Installation of a data logger on the largest two adjacent farms is suggested.

3. UNDER SKIN BROWNING

During the 2009/10 mango season all fruit consignments from the NT had to be re-sorted at markets due to USB, with 24% of the premium fruit downgraded. This had a direct cost of $180,500. This cost could reach up to $1 million per year when all NT trees are in full production if this problem is not addressed. These estimates do not include losses in other varieties.

Mango fruit undergo several procedures from harvest to arrival at market. In Australia most are harvested using harvest aids with either detergent sprays or dips to prevent skin damage from the sap that spurts or oozes from the detached stem (Johnson and Hofman 2009). In the packhouse the fruit are brushed and given fungicide and insecticide treatments depending on market requirements.

'Honey Gold' fruit sometimes develops USB by the time the fruit arrive at the wholesale markets, which has been seen to a lesser degree in other cultivars such as 'Kensington Pride', 'R2E2' and Calypso^{TM} (Campbell 2007). Under skin browning is usually not visible at harvest, and the affected area is not sunken nor the flesh affected (Hofman et al. 2009). The injury is localised underneath the epidermal layers, resulting in a 'bruise' like symptom, usually with a discrete boundary. There is no visible damage to the cuticle or the epidermal and mesocarp cells. A discrete layer of starch can surround the resin canals in the skin, similar to that found with heat scald (Campbell 2007; Holmes et al. 2010). In severe cases the cells below the cuticle are highly desiccated, with the cell contents shrunken and disassociated from the cell walls.

Very little is known of why and how USB develops, or the anatomical/biochemical processes involved. Under skin browning is thought to be associated with some form of injury, or possibly the result of multiple conditions (Campbell 2007). Usually, areas injured by USB are either in contact with another fruit, the packing container, or the lower half of the fruit as it is packed (Campbell 2007; Holmes et al. 2010).

The very early stages of USB are characterised by a slightly brown "netting" underneath the skin that appears to be caused by discoloured latex vessels. Bezuidenhout et al. (2005) noticed a brown pigment in the cells surrounding the latex vessels similar to that in the cells surrounding discoloured lenticels. It is possible this brown pigment is the cause of the initial symptoms of USB, and further collapse of adjacent cells occurs as the disorder progresses. The accumulation of starch granules around the latex vessels in USB affected areas (Campbell 2007) may also contribute to the apparent discolouration of these vessels.

Rapid temperature changes after harvest, excessive storage times or incorrect storage conditions seem to influence the development of USB, but the causes are uncertain. Commercial experience indicates that holding the fruit at or above 18°C significantly reduces USB development in susceptible fruit. However, this restricts commercial flexibility, especially considering that fruit from the tropics require at least three days road transport to reach the main eastern seaboard markets. Preliminary work conducted in 2008 (as part of the MGO6022 project) showed that one-day delay at ambient temperatures between picking and packing, and two days at 18°C after

packing and before placing at 12°C, significantly reduced USB. Similarly in 2009, holding fruit for one day at 18°C then one day at 15°C before placing at 12°C reduced USB compared to placing at 12°C immediately after packing. Decreasing the rate of pulp temperature reduction also resulted in less USB. For example, wrapping the trays with cardboard delayed reaching 12°C by about 24 hours compared with no wrapping, and reduced USB incidence by about 30%.

Reducing the rate of cooling may increase the potential for 12°C storage, but the delay between harvest and cooling to 12°C may affect the storage life, and the potential to seafreight fruit to export markets. This needs to be investigated further.

In MG06022, USB was also often associated with physical damage to the fruit, which can be caused during road transport. In one trial, 79% of USB lesions in fruit transported from the NT to Brisbane were associated with obvious, recent physical damage (not healed field blemishes); non-transported fruit kept under similar transport temperatures had minimal USB. Most physical damage in the transported fruit appeared to be associated with the plastic tray insert as ridges around the top of the cup caused vibration damage to the skin. Transporting fruit in bubble wrap significantly reduced physical damage and USB. Using polystyrene socks, or bubble wrap on the bottom of the tray instead of inserts also reduced USB, but to a lesser extent.

Surprisingly, in one trial USB severity was not higher in fruit after commercial picking and packing compared with fruit that were hand-picked from the same trees direct into trays. Also, dropping fruit from 10-150 cm onto a hard smooth surface did not increase USB. These treatments may not have caused the type of damage to the skin as required for USB, but impacts against sharper edges and the stems of other fruit may do so and thereby contribute to USB. Despite the involvement of skin damage, it may not be the only requirement for USB development, since larger USB patches often appear on the fruit where there are no signs of skin injury.

Growing conditions are also involved in USB expression. Fruit susceptibility is usually higher in fruit from tropical production areas around Darwin and Katherine (NT) and less when fruit is grown in higher altitudes inland from Cairns (QLD), such as the Atherton Tablelands (Hofman et al. 2009). It has not been detected in subtropical productions areas from Bowen (QLD) south. The reasons for this are not understood. It is possible that fruit from the hotter production areas are more susceptible because of greater difference between fruit field temperature and air temperature during cooling (average temperatures in the last month of fruit growth are about 6-8°C higher in Darwin-Katherine than in Atherton) and/or fruit physiological differences. However, that needs to be investigated.

In addition, differences in USB expression between commercial farms in the Katherine area have been observed. During the 2009 research trials, fruit from three farms were harvested and treated in the same way, but had significantly different USB severity. Also, over the whole Katherine season farm differences were observed in the percentage of fruit with USB at the markets.

In summary, the preliminary results from the MG06022 project and commercial experience suggest that several factors are likely to cause USB. Further investigation is required to confirm whether postharvest practices identified in project MG06022 could be combined to effectively

prevent or minimise USB in 'Honey Gold' mango under commercial conditions. Considering that USB is not evident until fruit reaches markets (thus it cannot be sorted in the packhouse), identifying production factors that make the fruit susceptible to USB development after harvest is also warranted.

The USB research consisted of the following components:

- A standard USB test
    - Most of the trails required a consistent test that can be applied to different treatments to compare susceptibility
- How can we grow more robust fruit?
    - The climatic and edaphic characteristics of nine commercial blocks from the NT to SE Queensland were monitored and fruit assessed for USB sensitivity. The intent was to identify key production characteristics that contribute to producing robust fruit. The trial was repeated for three seasons.
    - Several potentially promising fertiliser treatments were tested.
    - Fruit position in the canopy, based on the observation that USB is more common on blushed fruit
- Harvesting practices
    - Maturity
    - Diurnal harvesting effects, since fruit in the morning are firmer (more turgid) and more likely to be damaged from impacts etc during harvesting
    - Desapping
    - Compression damage in the half ton field bins
- Preventing damage during transport
    - Semi-commercial testing of tray inserts, plastic wraps etc

These trials are described below.

3.1. The standard USB test

3.1.1. Summary

Results from project MG06022 indicated under skin browning (USB) is often associated with rapid reduction in temperatures after harvest and physical damage to fruit caused during harvesting and packing, or from abrasion damage with tray inserts or trays during transport. Hence, a standard USB test that combined lightly abrading with sandpaper and placing at 13ºC was tested. Results showed that pulling the fruit over ½ sheet (70 mm long) of 220-240 grit sandpaper, holding at 12-13ºC for six days, then ripening, caused USB to develop on up to 80% of the fruit. The abrasion treatment was applied by pulling the fruit over the sandpaper, but this resulted in significant variation in the area of the skin abraded. Further refinement involved using a cheap, small orbital sander held in a pivot arm to apply a constant 105 gm of weight onto the fruit, and abrading for 1 sec while holding the fruit firm.

3.1.2. Introduction

Within this 'Honey Gold' project six field sites were established from the NT through to southern Queensland to determine the effects of growing conditions (climate, tree and soil

factors etc) on USB susceptibility. A standard and consistent USB test was required that could be applied to the fruit from the six sites.

Previous research in project MG06022 suggested that rapid reduction in fruit temperatures to about 13°C soon after harvest, in combination with some form of physical damage were important for USB development. Physical damage can occur during transport from sharp plastic tray inserts, but this is too inconsistent for a standard test. Preliminary tests indicated abrasion of fruit with sandpaper can also stimulate USB development. Thus, a suitable standard test was likely be achieved by combining abrasion and low-temperature storage.

Other observations suggest that USB can still develop with considerable delay between placing at low temperatures and the physical treatment. For example, fruit were held at 14°C for 4 d without any sign of USB, but USB was present once these fruit were transported to Brisbane. Also, commercially handled fruit showed no USB in Adelaide, but fruit from the same consignment on-shipped to Perth had USB. Hence there is little understanding of the effects of delays between cooling and physical damage.

The following trials developed a USB test using sandpaper to simulate physical damage, then holding at 13ºC for about 6 d before ripening.

3.1.3. Materials and methods

3.1.3.1. Treatments

'Honey Gold' fruit (10 fruit per treatment) were hand harvested at early maturity (7th November 2011) from a commercial farm in the Katherine region, carefully placed into single layer, 7 kg trays then air freighted to Brisbane. The fruit arrived at the Maroochy Research Facility (MRF) within 1 d of harvest.

The fruit were randomly divided into the treatments. The relevant treatments (Table 14) were placed at 13ºC overnight before abrading, or abraded before placing at 13°C. The abrasion treatment was applied by pulling the fruit by the stem button over the sandpaper, guiding the fruit with two fingers either side of the fruit to make sure the same part of the fruit remained in contact with the sandpaper (Plate 2). This was to ensure consistency in the area of the skin being abraded. No downward pressure was applied. The treatment was applied of four areas around the largest circumference of the fruit. For those fruit with no remaining stem, a nail or screw was inserted into the stem scar to provide a "handle" to pull the fruit.

The following sandpapers were used:

- 40 grit – KMCA garnet G62 garnet electro coated dry sanding abrasive paper – Red
- P180 grit – KMCA non clog A62N aluminium oxide electro coated dry sanding abrasive paper
- P240 grit – KMCA non clog A62N aluminium oxide electro coated dry sanding abrasive paper
- P400 – KMCA wet dry S85 silicon carbide electro coated water proof abrasive paper
- Four types of sandpaper; 40, 180, 240 and 400 grit sandpaper.

Norton paper of the same grit is similar to the above.

The three "lengths" of abrasion were:

- 140 mm long x 230 mm wide (half full sheet)
- 280 mm long x 230 mm wide (full sheet)
- 280 mm long x 230 mm wide – twice

Table 14 Treatments applied to 'Honey Gold' fruit to develop a standard USB test. The fruit were abraded either before placing at 13ºC, or one day after placing at 13ºC. Abrasion was applied with sandpaper of several grit ratings, and pulling the fruit across either half the width (70 mm) or the full width (140 mm) of the sandpaper. The 280 mm treatment was applied by twice pulling over 140 mm.

	Timing of abrasion	
Treatment	Before 13°C	After 13°C
Control	Y	
140 mm 40 grit	Y	
140 mm 180 grit	Y	
140 mm 240 grit*	Y	
140 mm 400 grit	Y	
70 mm 40 grit	Y	
280 mm 40 grit	Y	
140 mm 40 grit		Y
140 mm 180 grit		Y
140 mm 240 grit		Y
140 mm 400 grit		Y
70 mm 40 grit		Y
70 mm 180 grit		Y
70 mm 240 grit		Y
70 mm 400 grit		Y

Similar size fruit (typically count 12-14) were used and the fruit weighed within 1 d of treatment.

Plate 2 Hand and sander application of the abrasion treatment for the standard USB test.

Other tests included puncturing the fruit with small nailheads to simulate the sharp sections of tray inserts, but these tests were not successful.

3.1.3.2. Assessment

The fruit were assessed every day while at 13 ºC for at least 5 d, then removed to 20°C and assessed at eating soft.

The fruit were rated for USB using the following scale:

0=nil
1=USB just visible
2=spend up to 5 mm from the abraded area
3=spread up to 20 mm
4=spread more than 20 mm, solid
5=spread more than 20 mm, scattered

The number of abrasion points that developed USB was also recorded.

3.1.4. Results and discussion

There was no significant effect of sandpaper or distance, or timing of cold treatment on USB severity (Table 15). About 40-50 % of the fruit developed USB.

On the basis of these results 240 grit sandpaper and 70 mm abrasion length was selected as the standard treatment. The fruit were abraded before placing at 13ºC to prevent complications with condensation on the fruit if they had been held at 13ºC before treatment.

Experience with this test in 2011/12 indicated operator error in the area of the fruit abraded because the fruit can "roll" while being abraded (Plate 3). More consistent procedures were investigated in 2012 using fruit from the Katherine area as above. The final procedure consisted of:

- an Ozito orbital sander, model OZDS280WA, set at low speed (setting 1)
- The sander secured in a pivot arrangement so that the weight at the contact point with the fruit was about 105 gm.
- The sander was switched on then lowered onto the fruit and the fruit "sanded" for 1 second.
- The fruit held firmly in a small sand bag to prevent movement of the fruit so that a constant area of the fruit skin was abraded.

This procedure was adopted in all new trials from 2012.

Table 15 Under skin browning (USB) severity (0-5), the number of fruit with USB and the total number of abrasion points showing USB, on 'Honey Gold' fruit abraded with sandpaper of differing grit and length (the distance the fruit were "pulled" over the sandpaper) of abrasion, either before placing at 13ºC or holding overnight at 13ºC before abrasion.

Sandpaper		Average severity	Incidence (%) of	No. of lesions per
Grit	Length (mm)	(0-5)	fruit with USB	treatment
Abrasion before placing at 13ºC				
40	70	0.3	40	5
40	140	0.4	50	6
40	280	0.2	30	4
180	140	0.3	50	9
240	140	0.4	40	8
400	140	0.4	40	6
Average		0.33	41.7	6
Abrasion after 1 d at 13ºC				
40	70	0.6	44	11
40	140	0.3	40	5
180	70	0.5	67	11
180	140	0.3	30	7
240	70	0.5	78	12
240	140	0.5	70	11
400	70	0.2	33	5
400	140	0.4	40	10
Average		0.41	50.2	9

Plate 3 Variation in the area of the fruit affected using the hand applied abrasion treatment

3.2. Production factors and USB (USB Survey)

3.2.1. Materials and methods

3.2.1.1. Sites and fruit

In Year 1 (20011/12) Tiny Tag data loggers [Ultra 2 Internal Temperature and Tiny tag Plus with tipping bucket rain gauge] were purchased and installed established at eight sites. In Year 2 (2012/13) an additional logger was installed at Pinata farm in Rockhampton (CQ). Site details are given in Table 16. These sites were used to collect data both for the USB production and the crop forecasting components. Ten trees were labelled at each site for fruit sampling.

Table 16 Sites used in the "Production factors" trial.

Grower	Location	Block	Yr planted /grafted	Rootstock	Spacing (m)	Trees/ha	Soil Type
Pinata Fox Road	Katherine NT	Valve 8	2004	KP	8 x 4	312	Deep Sand
Peter Deans	Katherine NT	HG 2	2003/4	3 types of common	7 x 4	357	Sandy clay, edge of clay zone
Pinata	Mataranka NT	Middle	2005	KP	8 x 4	312	Sandy loam. Not as deep at Fox Road
Maurice Cetinic	Mareeba FNQ	9	2005 grafted*	KP	6 x 10	166	Gravel ridge where logger is
Adrian Zugno	Mutchilba, FNQ	Shelby 2nd row	2005	KP	7 x 5	286	Grey brown sandy loam
Lionel Williams	Bowen NQ	C1 moved to C2 year 2	2001	Most KP Some R2E2	3.5 x 8 variable	357	Sandy loam
Pinata	Rockhampton CQ	F	2004	KP	7 x 3	476	Heavy self mulching clay
Tom Gorton	Outside Bundaberg SQ	Anicar	2004 & 5	KP	8 x 2	625	Sand
Pinata	Wamuran SEQ	A-D	2002	KP	6 x 3	555	Granitic sandy loam. shallow

*Field grafted on large old KP'

3.2.1.2. USB test and assessment

At standard commercial maturity, one tray per tree was harvested and the fruit desapped in Mango Wash then dried. Within 6 h of harvest the fruit were abraded then placed at 13ºC for about 6 d (section 3.2.1.2). They were then placed at about 20ºC to ripen and assessed for USB using a 0-5 rating scale (section 3.2.1.2).

3.2.1.3. Statistical analysis

Statistical analyses were performed by Genstat® 14 for Windows™ (VSN International Ltd., UK). The 'General Analysis of Variance' model was used, with farms as 'treatment' factor and

no blocking (trees were considered as replicates). The least significant difference (LSD) procedure at P = 0.05 was used to test for differences between treatment means.

3.2.2. Results and discussion

3.2.2.1. Temperature

Data logger information is summarised in Figure 4 and Figure 5. As expected, the NT sites over fruit development phase (stage i until harvest) had higher minimum, maximum, and average daily temperatures than other areas over the three years (Figure 4).

North Queensland which for this purpose included Mareeba, Mutchilba, Bowen as well as Rockhampton was warmer than SEQ (Bundaberg and Wamuran) especially with daily maximums. These differences are reflected in days from flowering to harvest.

In the Northern Territory where the low temperatures needed for flower initiation are more marginal, there are some differences between the three 'Honey Gold' farms in minimum temperatures, especially in the early stages of fruit growth with Fox Road being warmer than the other two farms. Fox Road has a higher elevation (194 m above sea level) than Mataranka (148 m), and Deans (115 m). However there was little difference in maximum temperatures, although Deans was slightly hotter. Fox Road was the warmer farm based on average daily temperatures Figure 5).

3.2.2.2. Rainfall

The nine data logger sites differed in the amount of rain and wet days from flowering though to harvest with year to year variations also apparent (Table 17). Northern Territory and North Queensland have pronounced wet (summer) and dry seasons. The more southern sites are more likely to receive winter rains and also rain at other times throughout the year.

The three NT sites (Deans, Fox Road, and Mataranka) are normally very dry with most rain occurring just at harvest time at the start of the wet season. Showers normally commence in this area about mid November. Other than this rain, there was minimal rain between stage i and harvest (Table 17).

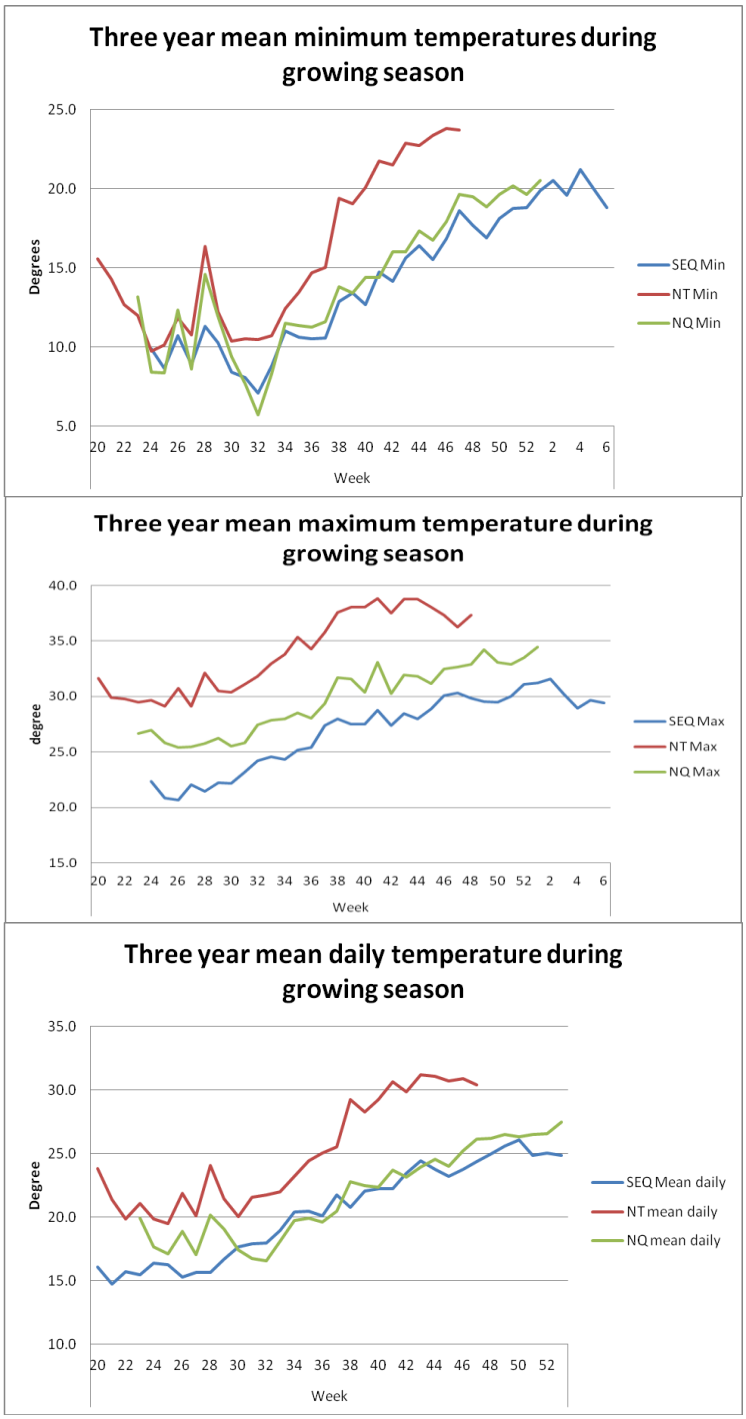


Figure 4 Three year mean daily minimum, maximum, and mean temperatures at logger sites

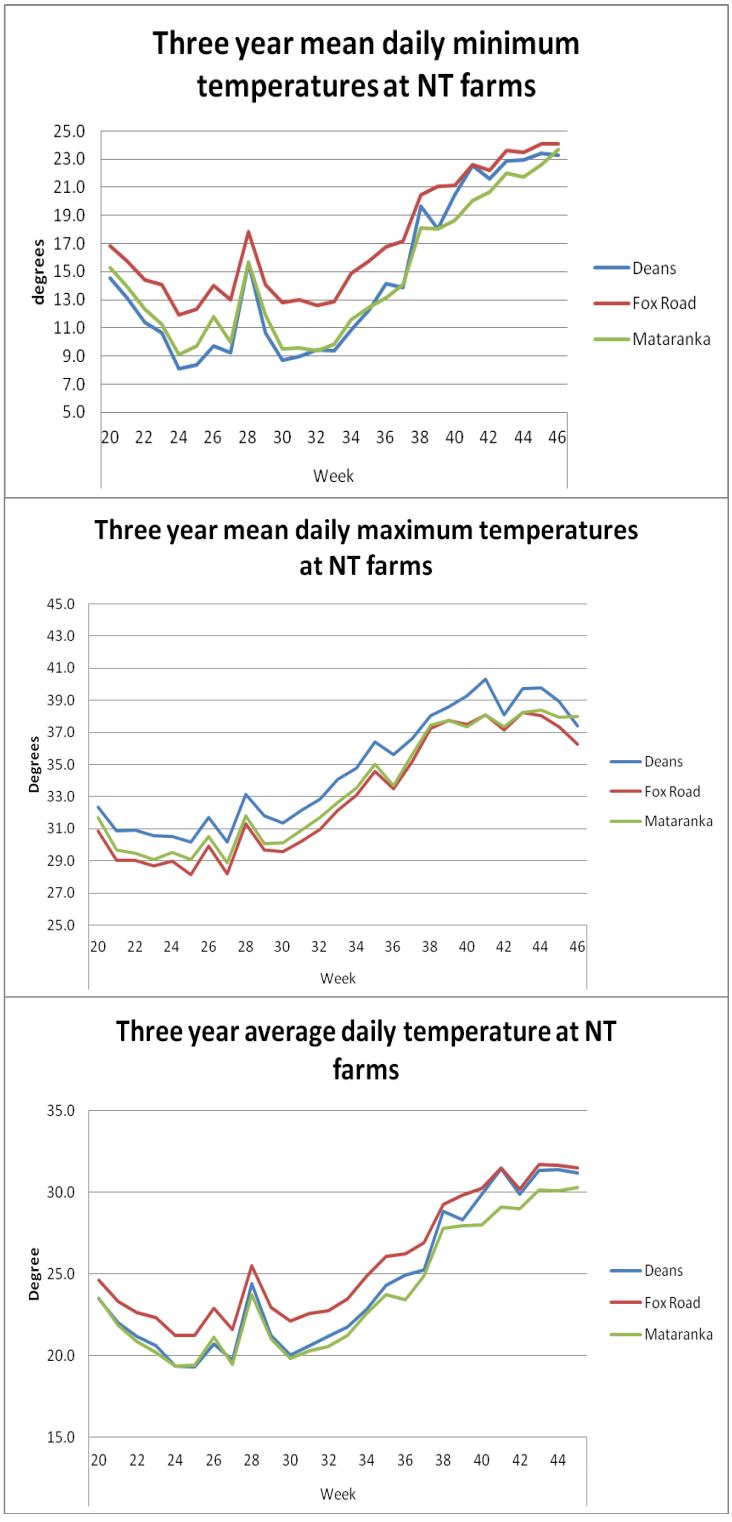


Figure 5 Three year minimum, maximum, and mean daily temperatures at the Northern Territory sites used in the USB survey trials

Far North (Cetinic and Zugno) and North Queensland (Williams) were also dry but data showed that unlike the Northern Territory sites, these farms were more likely to have rainfall events scattered over the growing period. Cetinic (close to the coastal range behind Cairns) often

received a lot of mist which did not register as more than a trace in the data logger. Zugno (further from the coast) does not get this weather. Cetinic has a much greater disease pressure because of the rain/mist, and in 2013/4 suffered a lot of fruit staining partly from 150 mm of rain in a short period of time.

Rockhampton, Gorton (Bundaberg) and Wamuran have high rainfall during the growing season. This especially impacts on flower survival and disease incidence especially at Wamuran.

Table 17 Total rainfall and number of wet days from stage i until harvest at the USB survey sites

Grower	Location	2011/12		2012/13		2013/14	
		mm rain	No. wet days (>=0.2 mm)	mm rain	No. wet days (>=0.2 mm)	mm rain	No. wet days (>=0.2 mm)
Deans	Katherine NT	191.4	13	68.2	8	18	4
Pinata Fox Road	Katherine NT	160.2	19	56.6	5	22.4	5
Pinata	Mataranka NT	200.6	20	32.6	4	83.2	17
Cetinic	Mareeba FNQ	166	23	77	15	227.4	25
Zugno	Mutchilba FNQ	183	21	37.4	9	172.2	27
Williams	Bowen NQ	60.6	13	44.4	4	152.4	10
Pinata	Rockhampton CQ			216.2	36	309.5	30
Gorton	Bundaberg SEQ	425.5	41	672.8	34		
Pinata	Wamuran SEQ	1291.2	75	416.8	42	241.9	44

3.2.2.3. Cultural practices

Paclobutrazol

Paclobutrazol (PBZ) is a plant growth regular used to stop vegetative growth and to promote flowering especially in hotter areas. All Northern Territory sites use PBZ. Cetinic used in year 1 but not in years 2 & 3. Zugno used all 3 seasons. Williams started use in year 3. PBZ was not generally used in the CQ and SEQ sites.

3.2.2.4. USB

There were significant effects of farm location on fruit susceptibility to USB following application of the application of the standard USB test (

Table 18). Within the Katherine farms the Fox Road and Mataranka sites consistently produced the most susceptible fruit. FNQ fruit were also susceptible, but those from Bowen and south were more resistant. No USB was noted in fruit from Rockhampton and Wamuran.

Table 18 The percentage of 'Honey Gold' fruit (incidence) with more than 1 cm^2 under skin browning (rating of more than 1) following the USB test, and the % of abraded areas that produced USB. The fruit were obtained from the survey sites in each of the main production regions over three seasons.

Farm	Incidence (%) of fruit with USB>1			% abraded areas with USB		
	2011/12	2012/13	2013/14	2011/12	2012/13	2013/14
Deans	29 [c]	2 [d]	12.2 [c]		1 [d]	6.1 [c]
Fox Rd	91 [a]	39 [b]	60.1 [b]		20 [b]	33.8 [b]
Hayes		20 [c]			13 [c]	
Mataranka		59 [a]	93.4 [a]		40 [a]	65.0 [a]
A Zugno	51 [b]	34 [b]	3.0 [c]		25 [b]	3.0 [c]
Cetinic	53 [b]	4 [d]	3.0 [c]		1 [d]	4.2 [c]
W Bowen		10 [d]	4.2 [c]		7 [cd]	2.3 [c]
Rockhampton	0					
Wamuran	0					

Means in the same column with the same letters are not significantly different (P=0.05) as tested by LSD.

3.2.2.5. Deans versus Fox Road

The interesting comparison is the consistent and large difference between Deans and Fox Road in the Katherine district, and this has been confirmed in commercial shipments. These farms are only about 15 k distant. The main obvious differences between them are presented in Table 19.

Three irrigation water samples were taken from Fox Road and one from Deans. Fox Road uses bore water while Deans uses Katherine River water. Table 20 presents the direct comparison for the Oct 2013 samples.

Fox Road is close to or exceeds the upper limits in several of the results. In previous tests, Fox Road had excessive bicarbonate, total dissolved salts and total dissolved iron (not tested in 2013 tests). Overall, Deans has better quality irrigation water.

In 2011/12, USB and non USB fruit from both Fox Road and Deans were analysed for mineral concentrations of both skin (peel) and flesh. Deans had 98% higher manganese concentrations (95.5 versus 1.5 $mg.kg^{-1}$ for Fox Road) in the skin. Deans usually has high leaf Mn levels. Calcium concentrations at Fox Road were 44% higher than Deans (2375 versus 1650 $mg.kg^{-1}$). Molybdenum was 43% higher at Deans than Fox Road. Differences between other nutrients were less than 20% (data not presented).

Flesh analysis showed no difference in calcium and molybdenum concentrations (data not presented). However, Deans had 94% higher manganese concentrations (29 versus 1.6 $mg.kg^{-1}$). Flesh potassium was 38 % higher at Deans but this could have reflected timing and amounts of applied potassium.

Table 19 Obvious differences between the 'Honey Gold' Deans and Fox Road sites used in the survey trial.

Characteristic	Deans	Fox Road	Comment
USB	Very little	Plenty	
Soil	2 types, clay and sandy	> 50 m deep sand	Deeper at Fox Road
Irrigation	Under tree micro	Under tree micro	
Water source	River	Bore	River is much better quality
Temperatures	Slightly cooler winter, then hotter	Warmer winter	Not much difference
Rainfall	Similar	Similar	
Soil pH	Slightly acid-neutral. 6-7	Alkaline 8-9	pH consistently high at Fox Road.
Soil nutrients			Some differences but not fully compared over time.
Leaf nutrients	Higher in Mn, Zn, B and sometimes K Mn and B often excessive		Some differences
Rootstock	Common. 3 types most are PC common. Woodsie and Top End Rural	KP	Deans only farm with most being common
Pruning	More open trees	Denser trees	Higher yield at Fox Road
Spacing	7 x 4 m	8 x 4 m	
Cultar	Yes – over does	yes	
Crop load	Moderate/light	Good	Denser trees at Fox, more fertiliser used, different pruning

Table 20 Major differences in irrigation water between Fox Road and Deans in October 2013

Characteristic	Units	Deans	Fox Road	Recommended max.
Hardness	Calcite	8	311	100
Acidity/Alkalinity	pH	6.9	7.2*	6.0 – 7.4
Electrical conductivity	EC dS/m	0.05	0.6	0.65
Nitrate	NO_3 (mg/L^{-1})	0.34	5.67	40
Calcium	Ca (mg/L^{-1})	1.1	75.4	100
Magnesium	Mg (mg/L^{-1})	1.1	29.9	100

*pH in May 2012 and January 2008 was 7.8

A more detailed assessment of the differences between these two sites, and trials in each of them to adjust growing conditions (e.g. irrigation water and frequency) may provide leads on how to grow more resistant fruit on the Fox Road farms, and on other farms.

3.3. Nutrition and water stress

3.3.1. Materials and methods

'Honey Gold' trees at the Fox Road near Katherine, NT and the Roper River farm near Mataranka, NT were exposed to ten nutrition and water stress treatments (Table 21). Ten trees within each trial block were randomly selected, and 14 fruit (one tray) were picked from each tree. Fruit were de-sapped and taken to the Katherine Research Station as described above. The skin on opposite sides of individual fruit was abraded as outlined above. The fruit were held at 13°C for 6 days and then transferred to 20°C for 3-6 days for evaluation. All remaining fruit on trees at both farms were then harvested by a commercial crew using harvest aids. These fruit were transferred to the packhouse and run along the packing line one block at a time according to commercial practice. Twelve trays of fruit from each field trial were then built into a single pallet such that one representative tray from each trial was included in each layer of the pallet. The sample pallet was loaded at the very rear driver's side of the truck trailer where maximum vibration occurs. The fruit were road-freighted to Wamuran at 16°C within 2-3 days. Upon arrival, the fruit were inspected for out-turn quality and transferred to 20°C for 6 days and assessed as described previously.

Table 21 Treatments applied to increase the resistance of 'Honey Gold' fruit to under skin browning at harvest. The treatments were applied to commercial farms at Fax Road and Mataranka. All treatments were used at the manufacturer recommended rates.

Treatment	Time of application
Control	Nil
Copper foliar (Kocide at 200 g/100 L+Agral wetter)	From fruit set to harvest, every 14 d
Firmrite Clear B (17% Ca)	From flowering stage g-j, weekly through flowering, then 14 day intervals
Screen Duo 1.25 kg/100 L + Agral wetter	Started at early fruit set, then every 14 d until harvest
Double Gypsum application (~10 kg/tree)	Mid-late March
Water stress pre harvest. Step down, 60%, 30%, 15% in week 3, 2, 1 respectively	Started 3 weeks pre-harvest
Ken Wilson's Calcium (14% Ca)	Applied as foliar every time K_2SO_4 was applied
SKH Silicon foliar (15% K, 21% Si)	Fortnightly starting one month from fruit set
High K (24% K as foliar) from Organica	14 day intervals from flowering stage j
Crop-Set™ foliar	Panicle extension, end of flowering, fruit egg size and one month before harvest
Calcium Boron Plex from Spray Gro (calcium acetate, lignosulphonate and boron)	Started pre-flowering. Every 3-4 weeks through flowering/set and then every 14 d until harvest. Applied at 7-10 L ha^{-1}

3.3.2. Results and discussion

There were no significant or consistent treatment effects on USB (Table 22). None of the nutrition treatments gave a commercial level of USB control and the leaf and skin mineral analysis gave inconsistent results (data not presented). Water stress could not be properly evaluated due to pre-harvest rain events.

Further work to test the theory that water stress may increase USB is warranted. Based on the diurnal harvesting results, both withholding irrigation near harvest, and increasing irrigation during fruit growth, should be tested.

Table 22 The incidence and severity of USB on 'Honey Gold' mango fruit in response to various pre-harvest nutrition and water stress treatments. Fruit were harvested from the Fox Road farm in the NT, transported by refrigerated truck at 16°C for 2-3 days and assessed after 6 days at 20°C. Means followed by the same different letters are not significantly different at P=0.05.

Nutrition and water stress treatment	USB incidence (% with USB> 1 cm^2)	
	% of fruit	(% abraded areas)
Control	16 ^{bcd}	12 ^{bcd}
Copper foliar	18 ^{bc}	15 ^{bc}
Firmrite™ calcium foliar	11 ^{d}	9 ^{d}
Screen DUO™ foliar	19 ^{bc}	16 ^{bc}
Double gypsum ground applied pre flower	18 ^{bcd}	14 ^{bcd}
Water stress starting 3 weeks pre harvest	26 ^{b}	21 ^{b}
Ken Wilson's foliar calcium	36 ^{a}	31 ^{a}
SKH Silicon foliar	24 ^{b}	19 ^{b}
Hi K foliar potassium	13 ^{cd}	10 ^{cd}
Crop-Set™ foliar	13 ^{cd}	10 ^{cd}

3.4. Fruit position in the canopy

3.4.1. Materials and methods

The same five 'Honey Gold' trees at the Deans and Fox Road farms described in trial 1 were used to source fruit. Fourteen fruit (one tray) from both the sun-exposed and shaded regions of the canopy were picked at commercial maturity from each tree at 0800-1000. One additional tray of sun-exposed fruit showing blush and non-blush surfaces was also harvested from each tree. Fruit were de-sapped and taken to the Katherine Research Station as described above. The skin on opposite sides of fruit, including those with blush and non-blush surfaces, was abraded with sandpaper. The fruit were transferred to 13°C for 6 days and then maintained at 20°C for 3-6 days for evaluation of USB incidence and severity.

3.4.2. Results and discussion

The incidence and severity of USB was not significantly different on sun-exposed and shaded fruit surfaces at each farm (data not shown). Fruit from the Fox Road farm exhibited more USB than those harvested from the Deans farm, in line with observations from the survey trial.

3.5. Effect of maturity

3.5.1. Materials and methods

Ten of the control 'Honey Gold' trees from the trial Mataranka site at Roper River were used (section 3.3.1). Fourteen fruit (one tray) were harvested at 0900-1200 from each tree at 3, 2 and 0 weeks before commercial maturity. Fruit were immediately de-sapped, packed into trays, and taken to the Katherine Research Station for abrasion with sandpaper as described above. The fruit were maintained at 13°C for 6 days and then transferred to 20°C for assessment. An additional 10 fruit were harvested for % dry matter analysis.

3.5.2. Results and discussion

USB incidence was highest for fruit harvested within 2 weeks of commercial maturity (Table 23). Fruit that were picked 3 weeks before the commercial harvest developed relatively low levels of USB. While these results indicate a significant effect of maturity on susceptibility, they have little commercial significance because fruit cannot be harvested below about 15% DM because of unacceptable flavour in the ripe fruit. Future trials should test susceptibility of mature to very mature fruit.

Table 23 The incidence (% of fruit or abraded areas) of USB on 'Honey Gold' mango fruit as affected by harvest maturity. Fruit were abraded with sandpaper and held at 13°C for 6 days and assessed at 20°C. Means in the same column with the same letters are not significantly different at P=0.05.

Weeks before commercial harvest	Harvest and abrasion date	Dry matter (%)	Heat units	USB incidence (% with USB> 1 cm^2)	
				% of fruit	% abraded areas
3	9/11/12	14.5	1322	10 [b]	5 [b]
2	15/11/12	15.6	1526	64 [a]	44 [a]
0	27/11/12	na	1689	59 [a]	40 [a]

3.6. Diurnal effects

3.6.1. Summary

Observations suggested that under skin browning (USB) may be more severe in stressed fruit or in fruit with higher turgor pressure (e.g. fruit harvested in the early morning). Hence the effects of fruit growing in the sun-exposed areas of the canopy versus shaded, early morning versus mid afternoon, desapped versus not desapped and fruit on the top of the field bins versus those near the bottom was tested. The effect of fruit maturity on USB was also examined.

Contrary to expectations, fruit harvested in the morning developed less USB after treatment with the standard USB test compared with those harvested in mid afternoon. The effects were significant and consistent across two farms. This indicates a very promising avenue for USB control.

3.6.2. Introduction

Observations from the 2011/12 trials indicated more USB on or near the blush areas of fruit, and on blushed fruit. The development of red blush is considered a protective response of the fruit against potentially harmful energy from the sun. Hence the hypothesis was developed that under skin browning (USB) is more likely to develop when the fruit are slightly stressed, such as when exposed to the sun on the tree.

Also, given that USB appears to be associated with resin canal dysfunction, and maybe the leaking of resin from the canals under pressure, it was possible the more turgid fruit early in the morning were more susceptible to cell and canal rupturing under the pressure of harvest. On this basis, factors such as not desapping (retaining the turgor pressure in the canals) and fruit near the bottom of the bin being exposed to greater compression forces than those on the top of the bin should contribute to USB development.

This trial studied the effects of harvesting in the early morning compared with mid afternoon using fruit from Katherine and north Queensland

3.6.3. Materials and methods

3.6.3.1. Treatments

Five ‘Honey Gold’ trees were randomly selected at two farms near Katherine, NT (Deans, Fox Road) and one farm near Mareeba. Fourteen fruit (one tray) were picked at commercial maturity from each tree in the morning (0730-0830) and afternoon (1500-1530). Fruit were de-sapped in Mango Wash and packed into trays. The fruit from the NT were transported by car to the Katherine Research Station within 1 hour, while Mareeba fruit were transported to the Pinata Mareeba pineapple shed within the hour. At each laboratory, the skin on opposite sides of each fruit was abraded with a half sheet of 240 grit sandpaper to simulate transport-related vibration injury. The fruit were then maintained at 13°C for 6 d then transferred to approx 20°C and assessed after 3-6 d once USB incidence and severity had reached a maximum.

3.6.3.2. Assessment

At approximately eating soft, the size of the USB lesion around each abrasion point was assessed based on the area of the lesion or the percentage of fruit total area affected, using the following scale (Holmes et al. 2010):

0=nil
1= less than 1 cm² of skin affected
2= 1-3 cm² (approximately 3%, area of five cent coin)
3= 3-12 cm² (approx. 10% of total fruit area)
4= 12 cm² (approx. 10%) to 25%
5= >25% of the skin effect of the skin affected

The number of abrasion points that developed USB was also recorded.

Incidence was calculated as the percentage of fruit with USB with rating greater than 1, or the percentage of abraded areas that produced USB of more than 1.

3.6.3.3. Statistical analysis

Statistical analyses were performed by Genstat® 14 for Windows™ (VSN International Ltd., UK), with the 'General Analysis of Variance' model used to analyse the data. A factorial design was used, with 'farm' times 'time of the day' used as 'treatments factors and trees as 'block' factor. The least significant difference (LSD) procedure at P = 0.05 was used to test for differences between treatment means.

3.6.4. Results and discussion

Fruit harvested in the morning from the NT farms displayed a lower incidence of USB relative to mangoes picked in the afternoon at each farm (Table 24). Fruit from the Mareeba farm showed the same trend. Fruit from the Fox Road farm exhibited the most USB, which confirms the findings from the survey trials (section 3.2).

This result was contrary to the hypothesis that early morning-harvested fruit would be more turgid and more susceptible to resin canal leakage leading to USB. However, the diurnal effect was strong and consistent for both NT farms, providing a significant lead to reducing fruit susceptibility. More trials are required to test the effects of 24 h harvesting.

Table 24 The incidence and severity of USB on 'Honey Gold' mango fruit from three farms as affected by the time of day of harvest. Fruit were abraded with sandpaper and held at 13°C for 6 days and assessed at 20°C. Data followed by different letters are significantly different.

Farm	Harvest date	% Dry Matter	Heat units	USB incidence (% with USB> 1 cm^2)			
				% of fruit		% abraded areas	
				AM	PM	AM	PM
Deans, NT	10/11/12	18.1	1658	0^{e}	16^{c}	0^{d}	8^{c}
Fox Road, NT	15/11/12	16.7	1744	31^{b}	70^{a}	16^{b}	48^{a}
Cetinic, Qld	11/01/13	15.5	1391	3^{de}	14^{cd}	1^{d}	4^{cd}

3.7. Desapping and field bins

3.7.1. Materials and methods

Ten of the control 'Honey Gold' trees from the skin toughening trial at the Roper River farm near Mataranka, NT were selected at random. A total of 84 fruit (six trays) at commercial maturity were harvested from the trees at 0900-1000. Half of the fruit (i.e. three trays) were immediately de-stemmed while the stems (3-4 cm-length) remained attached to all other fruit. All fruit were rinsed in mango wash using a harvest aid following commercial practice. The fruit were packed into trays and taken to the Katherine Research Station for abrasion with sandpaper as described above. The fruit were maintained at 13°C for 6 days and then transferred to 20°C for assessment after 3-6 days.

3.7.2. Results and discussion

There was no effect of de-stemming on the development of USB (data not shown).

3.8. Semi-commercial transport trails

3.8.1. Summary

Under-skin browning (USB) is a disorder that develops on 'Honey Gold' fruit after harvest. The disorder is usually not evident until fruit reach the wholesale market. Thus, fruit often need re-packing at the markets, causing considerable wastage and financial loss. Previous research suggested that USB results from an interaction between physical damage and low temperature (i.e. physiological stress) during transport and distribution. To address this issue, fruit from three farms in the Northern Territory were either cooled to 13°C within 10 hours of harvest, or held at 18-20°C for 1-2 days before cooling to 13°C. The fruit were packed within commercial fibreboard trays in either standard plastic inserts, a 'softer' insert to potentially minimise fruit damage, or were individually wrapped in plastic or bubble wrap to prevent any damage. The fruit were then palletised and transported for 3 days to southern Australia in a refrigerated truck. Delaying cooling after harvest for 2 days reduced the incidence of USB by 52-85%. As compared to using standard inserts and cooling immediately after harvest, the proportion of fruit with USB decreased from 25% to 3% when fruit packed with soft inserts were held at 18-20°C for 2 days before cooling at 13°C and transporting. These findings show that reducing the risk of vibration damage by using soft inserts in combination with a delay in temperature reduction after harvest can significantly reduce USB in commercial practice.

3.8.2. Introduction

'Honey Gold' is an Australian mango cultivar with attractive skin colour, a juicy, fibre-free flesh and a pleasant flavour when ripe (Sammon and Macleod, 1999). The fruit can develop under-skin browning (USB), a disorder characterised by a discolouration under the epidermis resulting in a grey-brown 'bruise'-like symptom, which can affect large areas of the fruit surface, but with no damage to the flesh (Holmes et al., 2010). The disorder is usually not evident until fruit reach the wholesale market, being a significant commercial problem on 'Honey Gold' mango grown in the warmer climates of the Northern Territory (NT), and at times North Queensland. Previous

research over two years suggested that USB can be reduced by slower temperature reduction after harvest (e.g. 18°C for 2-3 d, then 12°C) compared with rapid (e.g. 12-14°C within 13 h; (Marques et al., 2012). Physical damage during road-freight also appears to be an important contributor to USB, since fruit held at 12°C at the packhouse developed very little USB compared to fruit road-freighted for 3 d ((Marques et al., 2012). In addition, more careful packing of the fruit in bubblewrap or polystyrene socks significantly reduced USB compared with plastic inserts alone ((Marques et al., 2012). Those treatments were conducted under semi-commercial conditions with consignments from the NT to Brisbane. However, they have not been tested extensively, and the temperature and packaging treatments have not been tested in combination. Considering the potential benefits to industry, these aspects needed to be further investigated.

3.8.3. Materials and methods

3.8.3.1. Field sampling and handling

Commercially picked and packed 'Honey Gold' mango fruit were obtained from the end of the pack line on 19 November 2011 (one day after harvest) from three farms in the Katherine (NT) area. Fruit had been grown under standard commercial practices and harvested using harvest-aids at a maturity stage of approx. 16% dry matter (DM) or higher (Johnson and Hofman, 2009; Kernot et al., 1999). Fruit were washed, brushed, fungicide/insecticide treated, sorted and packed on a standard commercial packing line into single-layer cardboard trays (approx. 7.3 kg or 12 - 16 fruit per tray) with plastic inserts. A total of 81 trays were sampled (approx. 1100 fruit), with 45 of those trays re-packed into trays with the following packaging combinations (Plate 4):

- A softer insert made of expanded polystyrene material (the 'soft' treatments);
- Standard insert with fruit individually wrapped in bubble wrap of approx. 20 cm x 20 cm, covering only those parts of the fruit in contact with the insert, other fruit, or the tray wall (the 'standard/bubble wrap' treatment);
- Standard insert with road-freight with fruit individually wrapped in plastic wrap of approx. 20 cm x 20 cm, covering only those parts of the fruit in contact with the insert, other fruit, or the tray wall (the 'standard/plastic wrap' treatment).

The other 36 trays were kept untouched (the 'standard' treatments; Plate 4).

Trays were then divided into nine treatments (nine trays per treatment, with three trays per farm per treatment) and held at either 12-13°C or 18-20°C for periods of 0-3 d, as shown in Table 25.

After the 3 d holding period, nine trays were transferred to a cold room at the packhouse and held for about 7 d at 13°C (Treatment 2). The remaining trays were palletised and road-freighted for 4 d to Brisbane, Queensland (approx. 3,100 km) under standard commercial conditions in a solid-walled, refrigerated (temperature set at 13°C) articulated truck with airbag suspension. Fruit pulp temperatures were recorded every 15 min using Hobo loggers (Onset Corporation, Bourne, MA, USA) fitted with Type T thermocouple probes randomly inserted into one fruit from selected treatments representing the different temperature conditions.

Upon arrival in Brisbane, fruit were transported by car to the postharvest laboratory at the Maroochy Research Facility (MRF), Nambour (approx. 100 Km). All fruit were assessed for

external quality (as described below) and ripened at 20ºC. In the first 2 d of ripening, fruit were exposed to 10 µl.L^{-1} of ethylene.

Plate 4 Packaging options used in the trial: 'standard' plastic insert (top left); 'soft' polystyrene insert (top right; standard plastic insert with fruit individually wrapped in 'bubble wrap' (bottom left); standard plastic insert with fruit individually wrapped in 'plastic wrap' (bottom right).

3.8.3.2. Fruit quality assessments

Each fruit was visually rated for the severity of USB at the ripe stage. A six-point scale was used where 0 = no USB symptoms; 1 = less than 3% (1 cm^2) of skin surface affected; 2 = approx. 3% (1-3 cm^2); 3 = approx. 10% (3-12 cm^2); 4 = 10% - 25%; 5 = > 25% of skin surface affected (Holmes et al., 2010). The ripe stage was visually determined when ≥ 90% of skin colour changed from green to yellow (Holmes et al., 2010). The incidence of USB within each treatment was calculated as the percentage of fruit showing USB symptoms in relation to the total number of fruit examined per treatment. The severity of USB was calculated as the average severity rating of those fruit affected by USB in each treatment (unaffected fruit were excluded).

3.8.3.3. Statistical analysis

Statistical analyses were performed by Genstat® 11 for Windows™ (VSN International Ltd., UK). A completely randomise design was used with 9 trays used as replicates (3 trays per farm). The 'General Analysis of Variance' model was used to analyse the data, with the 10 treatments used as 'treatment' factor and farm/tray as 'block' factor. The least significant difference (LSD) procedure at P = 0.05 was used to test for differences between treatment means.

3.8.4. Results and discussion

Although transport was set at 13ºC, actual fruit pulp temperatures were about 16°C (data not shown), which partly compromised interpretation of the temperature data. However, delaying cooling for two days after harvest reduced USB incidence by 52-85% compared to holding fruit at 12-13 ºC before transport (Table 25). These results confirm previous research with 'Honey Gold' fruit ((Marques et al., 2012). It is not clear why this delay between harvest and cold storage can reduce USB, but holding fruit at warmer temperatures before cold storage may allow the fruit to ripen slightly, and mango fruit is more tolerant to chilling damage as they ripen (Mohammed and Brecht, 2002).

Table 25 Incidence (%) of under-skin browning (USB) in 'Honey Gold' mango fruit, as affected by temperature management before transport, packaging, and road transport

Treatment	Holding before transport (days)		Packaging (Insert/wrap)	Road transport at 16°C	Incidence of fruit with USB (%)
	18-20°C	12-13°C			
1	0	3	Standard	Yes	25 [a]
2	0	3	Standard	No	17 [abc]
3	0	3	Soft	Yes	20 [abc]
4	0	3	Standard/bubble wrap	Yes	22 [ab]
5	0	3	Standard/plastic wrap	Yes	15 [bc]
6	1	2	Standard	Yes	16 [abc]
7	1	2	Soft	Yes	5 [d]
8	2	1	Standard	Yes	12 [cd]
9	2	1	Soft	Yes	3 [d]

Means (n = 122) followed by the same lower-case letters are not significantly different ($P \leq 0.05$) as tested by LSD.

Road transport = transported for 3 d (3,400 km) by refrigerated truck at 16°C.

Fruit assessed at the ripe stage using a severity rating scale of 0 = no USB symptoms to 5 = > 25% of skin area affected.

Incidence = number of fruit with USB in relation to the total number of fruit examined per treatment.

The % of fruit with USB decreased by 73-92% in fruit packed with softer inserts and held for 1-2 d at 18-20°C after harvest compared with fruit packed with standard plastic inserts and no delay in cooling (Table 25). The use of softer inserts without a delay in cooling had little impact on the reduction of USB, suggesting that a combination of softer insert and delayed cooling is required for a more effective USB reduction. The reasons for these effects are unclear, but it is likely that the use of softer inserts may reduce the risk of vibration damage as physical damage is also associated with USB in 'Honey Gold' mango (Marques et al., 2012) and skin browning (O'Hare et al., 1999). Wrapping fruit in plastic wrap (but not bubble wrap) also reduced the incidence of USB compared to standard inserts (Table 25).

There was little significant impact of transport on USB in this study (Table 25), which contrasts with previous work where fruit transported at lower (12°C) temperatures had more USB

(Marques et al., 2012). There was also little difference in USB incidence between farms in this study (data not shown).

Overall, the results show that a combination of delaying fruit cooling for at least 2 d before transport combined with the use of soft inserts can potentially reduce USB in road-freighted ‘Honey Gold’ fruit.

3.9. Red lenticel

3.9.1. Introduction

'Honey Gold' mango grown in the cooler and wetter areas of central and southern Qld and northern New South Wales as compared with NT and North Qld often develop red halos around their lenticels during significant rain just before harvest. In severe cases, red streaks develop on parts of the fruit where rain and runoff from the above leaves frequently run down the fruit. Also, fruit grown in some areas, especially north Qld, can develop quite extensive areas of red and dark red discolouration on the skin surface. It is not known what the causes of this discolouration are and to what extent they may be a more pronounced form of red lenticels that have merged. In both cases, affected fruit are downgraded or rejected. In contrast, 'Honey Gold' fruit are relatively resistant to the widespread form of brown-black lenticel damage seen in other mango cultivars during and after harvesting and postharvest treatments.

Red lenticel in 'Honey Gold' is problematic on farms from Rockhampton south, which represents a smaller percentage of the total 'Honey Gold' production but the fruit are usually of greater value because of the later harvest. Up to half the fruit can be affected to varying degrees, largely based on how much rain occurs during mid-late fruit growth.

Lenticel damage on mango fruit can seriously affect visual appearance. Symptoms can be categorised into:

- lenticel spotting, which may develop via entry of water into the lenticel and the subsequent collapse and discolouration of adjacent cells (Rymbai et al., 2012).
- lenticel discolouration, which involves a halo of coloured skin around the lenticel, with or without a lenticel spot in the middle (Bezuidenhout et al., 2005; du Plooy et al., 2006).

There is little published information on pre-harvest practices affecting lenticel discolouration. Withholding irrigation for three weeks before harvest had no effect on red lenticel in 'Tommy Atkins' mango (Cronje, 2009a). In contrast, reduced irrigation resulted in less lenticel spotting in 'Tommy Atkins', 'Keitt' and 'Kensington Pride', as mentioned above. Likewise, severe lenticel spotting of several South African cultivars was positively correlated with low pan evaporation, high humidity and rainy conditions at harvest (Oosthuyse, 1998), while larger 'Kensington Pride' fruit from branches with higher leaf:fruit ratios had also more lenticel spotting.

Lenticel discolouration has occurred in NQ on several occasions following use of foliar fertilizers, especially what was thought to be high K foliar sprays after previous copper sprays where residues of earlier copper sprays may have remained in the lenticel.

Several postharvest practices are reported to reduce red lenticel in 'Tommy Atkins' mango: a one-day delay between picking and packing (Cronje, 2009a); not dipping fruit in de-sapping solution (calcium hydroxide) (Self et al., 2006); dipping fruit in salt solution for 2 or 5 min before packing (Cronje, 2009b); avoiding prolonged (e.g. 2-3 weeks) cold storage (e.g. at 9–12°C) (Pesis et al., 1997; Pesis et al., 2000; Self et al., 2006); conditioning fruit by gradually decreasing the temperature from 20°C to 17°C or 14°C during a 2-day period after harvest and

before storage at 9°C (Pesis et al., 1997) In addition, cultivar can also affect red lenticel, e.g., 'Tommy Atkins' showed greater sensitivity than 'Keitt' (Cronje, 2009a).

Red halos around lenticels likely involve the synthesis of plant pigments such as flavonoids, anthocyanins, and phenylpropanoid derivatives in sub-lenticellular cells (Dixon and Paiva, 1995; Du Plooy et al., 2009), possibly a plant response associated with biotic and abiotic stress signals. It is not clear what regulates pigment production in these instances; it may reflect changes in water potential or cellular pH caused by water or de-sapping solution entering the lenticels (Self et al., 2006).

Red skin discolouration has been a consistent problem with 'Honey Gold' grown on a northern New South Wales farm. Circumstantial on-farm experience suggests that this may be a stress response associated with ethylene. The same mechanisms may be involved in the red pigment formation around lenticels. Hence a preliminary trial was conducted in a south east Queensland farm using in-field fruit treatments with ethylene/stress related compounds. Commercial experience suggests that red lenticel develops when the fruit are exposed to rain during late fruit growth. Hence absence of these conducive conditions may result in nil treatment effects.

3.9.2. Materials and methods

3.9.2.1. Treatments

Twenty mature 'Honey Gold' trees were tagged on a commercial farm at Wamuran. Seven fruit were tagged on each tree to allow application of each treatment to one fruit on each of the 20 trees. The tagged fruit were on the eastern side of the tree since there were insufficient acceptable fruit numbers on the western aspect (lower fruit set and more sunburn). The following treatments were applied by dipping each fruit on the tree for 10 sec each:

1. Control; No dip
2. Water control; water containing 0.2% Agral
3. Ethanol control; 11.3 $mL.L^{-1}$ with 0.2% Agral
4. Ethrel® (Bayer; 720 $g.L^{-1}$ Ethephon); 1 $mL.L^{-1}$ with 0.2% Agral
5. ReTain® (Aminoethoxyvinylglycine); AVG; 150 $g.kg^{-1}$); 0.83 $g.L^{-1}$ with 0.2% Agral
6. Natural Shine (Campbell Chemicals; carnauba wax) at 2.5% (no Agral).
7. Methyl jasmonate (MeJa); 1.13 $g.L^{-1}$ with 0.2% Agral

The MeJa solution was made by dissolving 1.7 g MeJa in 17 mL absolute ethanol, then making up to 1.5 L with water. The ethanol control consisted of 17 mL in 1.5 L water. All treatments except 3 and 7 were applied on 23rd and 30th January. Treatments 3 and 7 were applied on 28th and 30th January. The fruit were harvested on 3rd February.

3.9.2.2. Assessments and statistical analysis

Every 3-4 d the number of red lenticels per fruit was recorded. Statistical analyses were performed by Genstat® 11 for Windows™ (VSN International Ltd., UK). A completely randomised design was used with approx 14 single fruit replications. The least significant difference (LSD) procedure at $P = 0.05$ was used to test for differences between treatment means.

3.9.3. Results and discussion

Table 26 indicates relatively little rainfall during the last weeks before harvest.

Table 26 Weekly rainfall in the last six weeks before harvest of the 'Honey Gold' trial on red lenticel

Week ending	Total rainfall (mm)
29/12/13	2.6
05/01/14	1.2
12/01/14	45.6
19/01/14	8.4
26/01/14	24.4
02/02/14	6.6
09/02/14	7

Table 27 indicates that all treatments had similar or higher red lenticel numbers compared with control. There were indications that ripening with ethylene decreased the number of red lenticels. Further research is required, but will be challenging because the defect generally requires considerable rain for expression.

Table 27 The average number of red lenticels on 'Honey Gold' fruit during ripening following field treatment with Ethrel, ReTain and Natural Shine (carnauba-based wax). Means in each column without letters are not significantly different (P=0.05) as tested by LSD.

Treatment	Days after harvest			
	2	6	9	13
Control (no ethylene)	7.5	14.3 [ab]	14.3 [ab]	13.7 [b]
No dip	5.6	6.4 [c]	6.9 [c]	7.3 [bc]
2% Agral	6.6	7.1 [c]	8.5 [bc]	8.9 [bc]
Ethanol	3.2	10.4 [bc]	12.4 [bc]	8.1 [bc]
Ethrel	4.0	5.1 [c]	6.3 [c]	6.9 [c]
Retain	5.2	6.9 [c]	7.5 [c]	7.5 [bc]
Wax	6.9	8.1 [c]	8.3 [bc]	8.4 [bc]
Methyl jasmonate	11.4	14.0 [a]	20.4 [a]	27.2 [a]

4. DEVELOPMENT OF ADDITIONAL OUTLETS FOR NON PREMIUM GRADE FRUIT

Second or juice grade fruit generally is used for juicing. Demand from manufacturers for juice varies widely between seasons. Market research is needed to find alternative outlets for non premium grade fruit which will help remove lower quality 'Honey Gold' fruit from the market and improve profitability of the 'Honey Gold' crop significantly by increasing the demand for premium 'Honey Gold' fruit.

The objectives of this R & D project were to find methods to overcome/reduce these issues and to provide best advice for production and handling of 'Honey Gold' mangoes.

For the 2011/12 season a 'Honey Gold' branded "bulk" or "Class 2" box was designed and made available to all 'Honey Gold' Growers. This is a 15 kg carton purposely made this weight to differentiate 'Honey Gold' in the marketplace from other bulk mangoes which are traditionally sold in 10 kg boxes. A 'Honey Gold' specification was also designed for the bulk pack to ensure consistency in packing of this grade in all packhouses. The bulk grade box was used for any fruit where the eating quality and shelf life of the mango was not affected but presented with more aesthetic marks and blemishes than Premium or Class 1 grade specifications allowed. This packaging has been successful and has been used in every region in 2011/12, 2012/13 and 2013/14 seasons. This means growers can put fruit they would usually put into juice in the bulk grade and it can be sold for a higher price per kilogram.

Developing export markets has been another main part of developing markets for non-premium grade fruit. Export markets have been developed in New Zealand, Dubai, Singapore, Hong Kong, China, Korea, Lebanon and Russia. The focus of export is on Class 1 fruit in size 8/9/10. These markets like the larger size fruit and can achieve a higher price than the Australian domestic market. In the 2013/14 season just over 9% of all Class 1 fruit was exported.

Piñata has also been working with fruit processing companies and exploring the option of doing 'Honey Gold' fresh cut tubs, frozen cheeks, dried mango etc. This work will continue on in following seasons.

5. TECHNOLOGY TRANSFER

5.1. 'Honey Gold' Congress

Every season a 'Honey Gold' Congress is held to gather together the entire 'Honey Gold' team including growers, wholesalers, retailers, agronomists, DAFF and the Piñata team. In 2012 the 'Honey Gold' Congress was held in Townsville from June 6th-8th, in 2013 in Cairns from May 13th-14th and in 2014 in Perth from May 6th-9th. This is the biggest event in the 'Honey Gold' calendar and is a great way to get the entire supply chain together to discuss the 'Honey Gold' System. Over 80% of 'Honey Gold' production has been represented at these congresses every year.

The congress includes conference sessions where production figures, sales figures, marketing activities, research and development activities and future strategy presentation are made and group discussions are held. In the past three seasons the Congress' have also included trips to 'Honey Gold' farms in Bowen, Mareeba and Carnarvon. Mini workshops are held on the farms in topics such a pest management and pruning and growers get a chance to talk to each other and the agronomist about their own crops. In Perth visits were made to the produce markets and three independent retail stores to see different styles of produce selling and marketing. All congresses include social activities such as dinners and river cruises. These congresses will continue to be held every year.

5.2. Training and farm visits

To help continue with development of a teamwork approach, Pinata staff and Tropical Horticultural Consulting have visited most farms to assist/address issues of concern to the growers.

Ted Winston of Tropical Horticultural Consulting has visited most of the 'Honey Gold' farms, especially in Queensland and the Northern Territory on a regular basis to advice growers on best practices such nutrition, pruning, and general crop agronomy and pest/disease management. He has provided a lot of on the job training with growers and staff. He currently does the nutrition programme on a private basis for a number of the properties.

Most growers need re enforcement of the basics and encouragement they are going in the right direction. Useful ideas are also gained which can be passed on to other 'Honey Gold' growers.

Gavin Scurr from Pinata is also a regular visitor to the farms and his team are in constant contact with growers re marketing and quality issues.

Dr Peter Hofman from DAFF has assisted many times in identifying postharvest quality issues both at the farm and market level. He and his team have been a most valuable resource in this time of diminished government assistance to growers.

5.3. Best Practice Manual

The 'Honey Gold' Best Practices Manual is in the process of being updated and the new edition will be distributed to 'Honey Gold' members before the start of the 2014/15 season.

5.4. Monthly critical inputs

Each month Ted Winston compiles a short list of critical issues that growers should be addressing that month. Growers often comment that they use the list as a check list to make sure they have undertaken the activities. An example of monthly critical inputs is given below:

‘HONEY GOLD’ CRITICAL ACTIVITIES – DECEMBER 2013

Harvest of the very light and late Mataranka crop is now underway. Other districts are looking more promising with harvesting to later this week in Burdekin/Bowen and in earlier Mareeba blocks. Some December harvest is also expected from Benaraby and maybe Bundaberg. Looks like a short compacted season at this point. One grower in Mareeba was unfortunate to be struck with an isolated storm causing fruit drop and quality issues. Let’s hope there are no more incidents such as this.

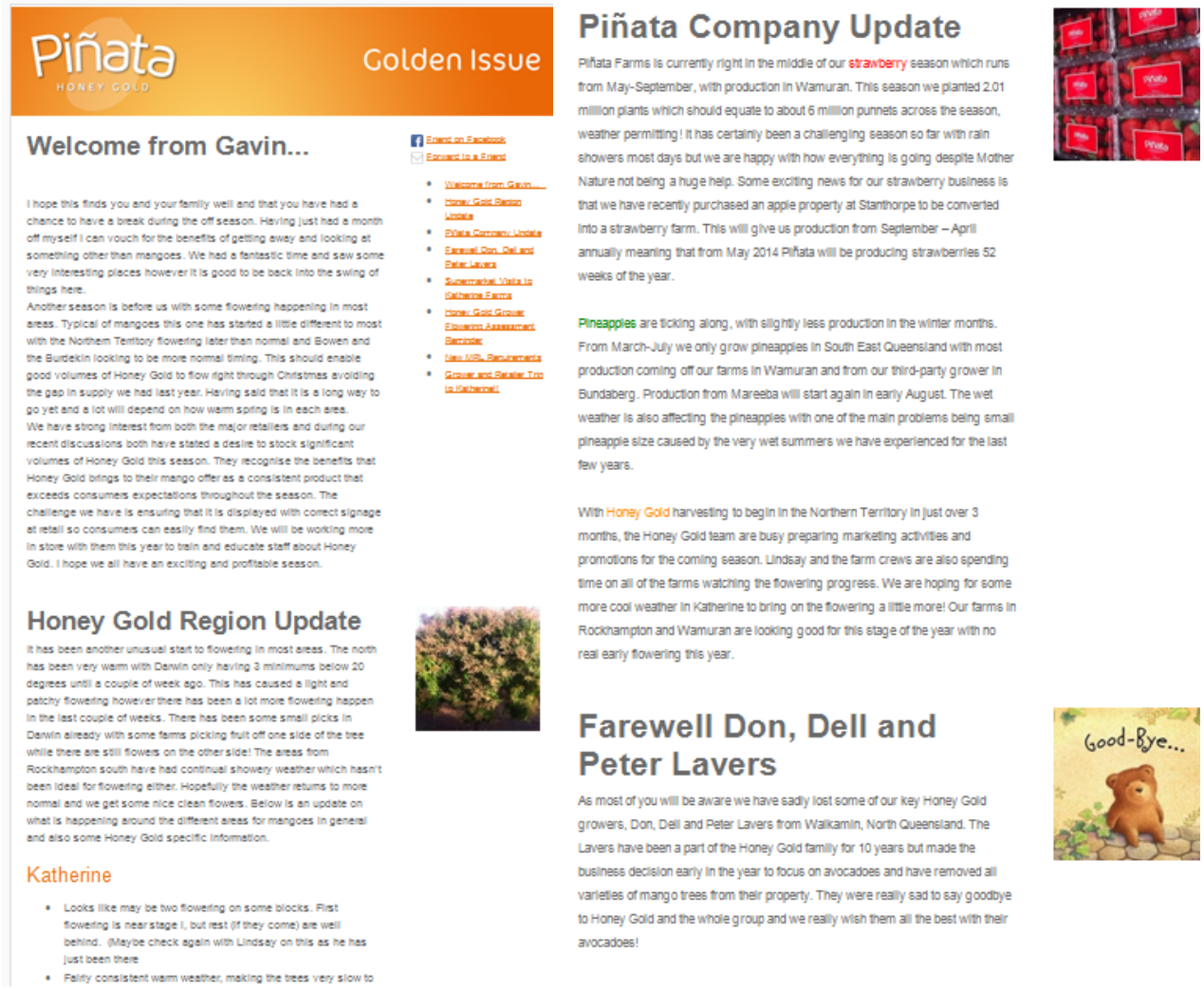
Growers are advised:

- Keep up protective fungicide sprays (Copper and Dithane) at regular intervals especially with wet weather. Remember to apply Aero 7 days or Amistar 14 days before harvest. Withholding periods are Aero 14 days and Amistar 3 days.
- Maintain regular potassium applications for fruit size. Increase rates if heavy crop and size down. Decrease rates if light crop and large fruit.
- Ease off irrigation slightly before harvest and/or if fruit gets too big.
- Be proactive re fly control.
- Watch out for late season mites, scale, flattids and associated sooty mould build-up – apply appropriate chemicals as/if needed. Beware of withholding schedules and check latest registrations first!!
- Conduct leaf and soil tests just before harvest so that you will be ready to go once harvest is finished
- Have mechanical pruners organized. Make sure machines are sterilized BEFORE entering your farm.
- Growers need to plan pruning, nutrition and paclobutrazol programmes and be ready to implement once harvest is finished.
- Hope for good weather and a lack of storms!

For more information refer to your ‘Honey Gold’ Production Manual

5.5. Honey Gold newsletter and web activity

The “Golden Issue” Honey Gold Newsletter is regularly sent to all Honey Gold growers to keep everyone up to date with any current issues, give region updates, Pinata updates and information on any other topics that are relevant at the time. The newsletters are sent through Mailchimp so they can be archived and also data is given on how many people open the newsletter etc. An example of part of one newsletter is as follows:



Piñata
HONEY GOLD
Golden Issue

Welcome from Gavin...

Friend on Facebook
Forward to a Friend

- Welcome from Gavin...
- Honey Gold Region Update
- Piñata Company Update
- Farewell Don, Dell and Peter Lavers
- Supermarket Visits to Katherine Farms
- Honey Gold Grower Education Assessment Reminder
- New MRL Requirements
- Grower and Retailer Trip to Katherine!

I hope this finds you and your family well and that you have had a chance to have a break during the off season. Having just had a month off myself I can vouch for the benefits of getting away and looking at something other than mangoes. We had a fantastic time and saw some very interesting places however it is good to be back into the swing of things here.
Another season is before us with some flowering happening in most areas. Typical of mangoes this one has started a little different to most with the Northern Territory flowering later than normal and Bowen and the Burdekin looking to be more normal timing. This should enable good volumes of Honey Gold to flow right through Christmas avoiding the gap in supply we had last year. Having said that it is a long way to go yet and a lot will depend on how warm spring is in each area.
We have strong interest from both the major retailers and during our recent discussions both have stated a desire to stock significant volumes of Honey Gold this season. They recognise the benefits that Honey Gold brings to their mango offer as a consistent product that exceeds consumers expectations throughout the season. The challenge we have is ensuring that it is displayed with correct signage at retail so consumers can easily find them. We will be working more in store with them this year to train and educate staff about Honey Gold. I hope we all have an exciting and profitable season.

Honey Gold Region Update

It has been another unusual start to flowering in most areas. The north has been very warm with Darwin only having 3 minimums below 20 degrees until a couple of week ago. This has caused a light and patchy flowering however there has been a lot more flowering happen in the last couple of weeks. There has been some small picks in Darwin already with some farms picking fruit off one side of the tree while there are still flowers on the other side! The areas from Rockhampton south have had continual showery weather which hasn't been ideal for flowering either. Hopefully the weather returns to more normal and we get some nice clean flowers. Below is an update on what is happening around the different areas for mangoes in general and also some Honey Gold specific information.

Katherine

- Looks like may be two flowering on some blocks. First flowering is near stage I, but rest (if they come) are well behind. (Maybe check again with Lindsay on this as he has just been there
- Fairly consistent warm weather, making the trees very slow to

Piñata Company Update

Piñata Farms is currently right in the middle of our strawberry season which runs from May-September, with production in Wamuran. This season we planted 2.01 milllion plants which should equate to about 6 milllion punnets across the season, weather permitting! It has certainly been a challenging season so far with rain showers most days but we are happy with how everything is going despite Mother Nature not being a huge help. Some exciting news for our strawberry business is that we have recently purchased an apple property at Stanthorpe to be converted into a strawberry farm. This will give us production from September – April annually meaning that from May 2014 Piñata will be producing strawberries 52 weeks of the year.

Pineapples are ticking along, with slightly less production in the winter months. From March-July we only grow pineapples in South East Queensland with most production coming off our farms in Wamuran and from our third-party grower in Bundaberg. Production from Mareeba will start again in early August. The wet weather is also affecting the pineapples with one of the main problems being small pineapple size caused by the very wet summers we have experienced for the last few years.

With Honey Gold harvesting to begin in the Northern Territory in just over 3 months, the Honey Gold team are busy preparing marketing activities and promotions for the coming season. Lindsay and the farm crews are also spending time on all of the farms watching the flowering progress. We are hoping for some more cool weather in Katherine to bring on the flowering a little more! Our farms in Rockhampton and Wamuran are looking good for this stage of the year with no real early flowering this year.

Farewell Don, Dell and Peter Lavers

As most of you will be aware we have sadly lost some of our key Honey Gold growers, Don, Dell and Peter Lavers from Walkamin, North Queensland. The Lavers have been a part of the Honey Gold family for 10 years but made the business decision early in the year to focus on avocadoes and have removed all varieties of mango trees from their property. They were really sad to say goodbye to Honey Gold and the whole group and we really wish them all the best with their avocadoes!

There is also a Pinata website – www.pinata.com.au and 'Honey Gold' website – www.honeygold.com.au where regular updates are posted about the company and Honey Golds for the general public and 'Honey Gold' growers to view. Pinata is also active on Facebook – www.facebook.com.au/pinatafarms where regular grower, farm and product updates are posted and talked about during the Honey Gold mango season

6. RECOMMENDATIONS

Improving packouts

- Further encouragement is needed to have a larger % of growers to see the benefits and participate in down grade analysis.
- Greater standardization in the methods of recording and transferring data from the farm to Pinata is needed.
- Pinata needs to have a rapid turnaround procedure to growers of analysed data and recommendations.

Crop Forecasting

- Use of 1500 accumulated heat units from stage i of the flowering chart (full flower) should be used to predict approximate time of fruit maturity and when to commence harvest. Growers still need to check both external and internal fruit characteristics to confirm maturity.
- A computer/iPad app needs to be developed for growers to rapidly determine predicted harvest maturity.

Under skin browning

Adoption of current project recommendations has reduced the commercial impact of USB but further R&D is required to identify how to grow more robust fruit and prevent USB development after harvest. The most promising areas are:

- Determining the causes for the consistent difference in fruit susceptibility between Deans and Fox Road farms
- Confirming the reliability of the diurnal effects USB, testing night harvesting under commercial conditions, and understanding the mechanisms involved with a view to developing further means of reducing USB.
- Minimising damage during transport that is consistently associated with increased USB. This includes testing softer inserts, and reducing vibration in pallets with e.g. pallet liners etc.

Red lenticel

The preliminary field trials did not reduce red lenticel in ripe fruit. A more detailed program would include:

- Literature survey to identify potential control measures
- Targeted laboratory trials, with the most promising treatments tested in field trials
- Extending the research to related defects such as fruit staining

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