Resin Canal Discolouration:

Cause, Effect, Management, Future Research

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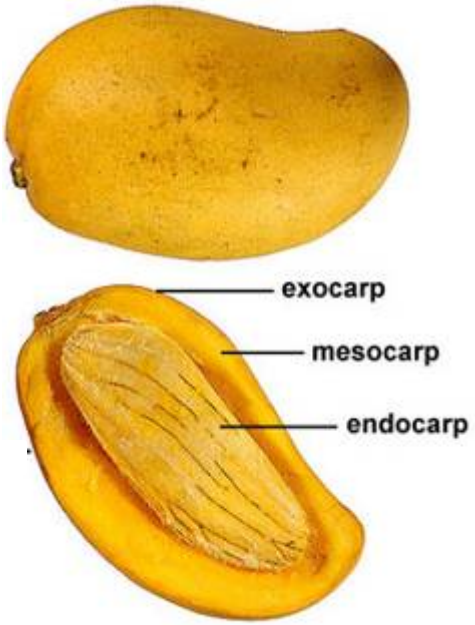
AUSTRALIAN MANGOES

W.E Pack

What are resin canals?

- A distinctive feature of several species including mango
- They store sap under pressure within the plant
- Canals form a network in mango fruit
- They may function as a chemical defence system against pests
- Resin canals are normally flesh-coloured



What is resin canal discolouration?

- Brown-black discoloured canals in ripening mango fruit
- RCD is sometimes visible through the fruit skin
- Reports of RCD have increased during the past few seasons
- Because RCD can develop after packing, there are concerns about its impact on consumers

What we know about RCD

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2. RCD can be found in green fruit with injury or infection

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What we know about RCD

Skin on

Skin off

What we know about RCD

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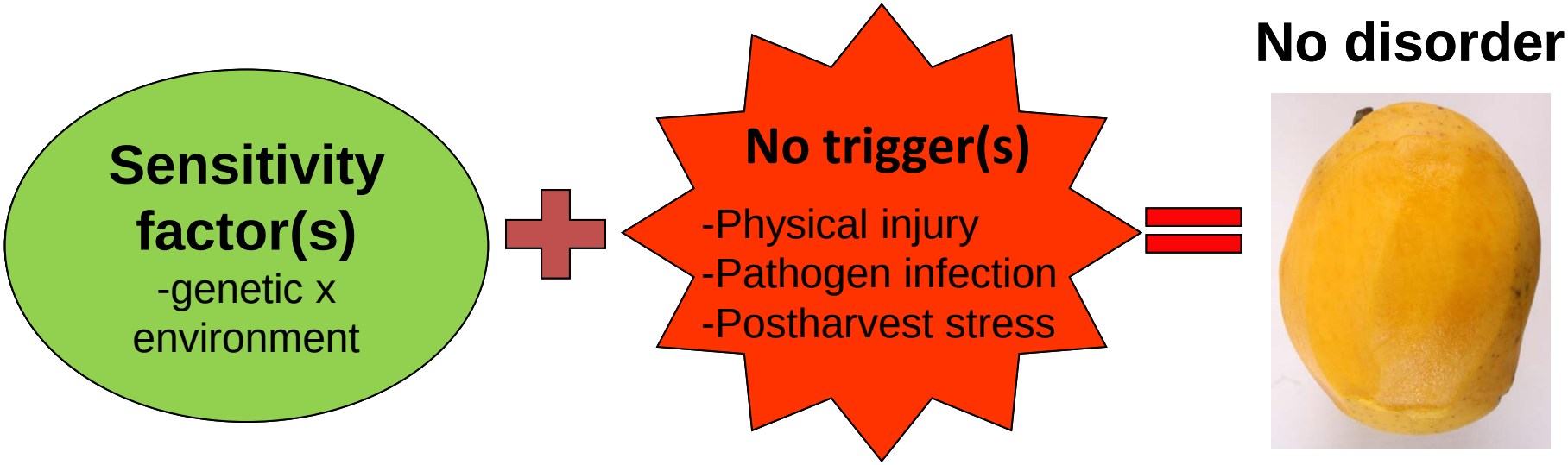
2. RCD can be found in green fruit with injury or infection
3. RCD incidence is higher in fruit that are commercially handled
4. RCD can be present in the flesh but not visible in the skin
5. RCD increases as fruit develop from firm ripe to eating ripe
6. RCD incidence can be higher in fruit picked early
7. RCD can be higher in fruit picked soon after rain
8. RCD symptoms may be associated with bacteria

Towards managing RCD

RCD is likely to occur when field conditions result in the production of ‘sensitive’ fruit that expresses the defect when exposed to harvest and postharvest stresses



Current research

Activities in 2014/15

1. Survey of growers about their experience with RCD
2. Establish a standard procedure for quantifying RCD
3. Sequential sampling of fruit from tree to market
4. Confirm the possible involvement of bacteria in RCD

1. Survey of practices

Objective

- Survey growers and packers from the Darwin area about their experience with RCD

Results

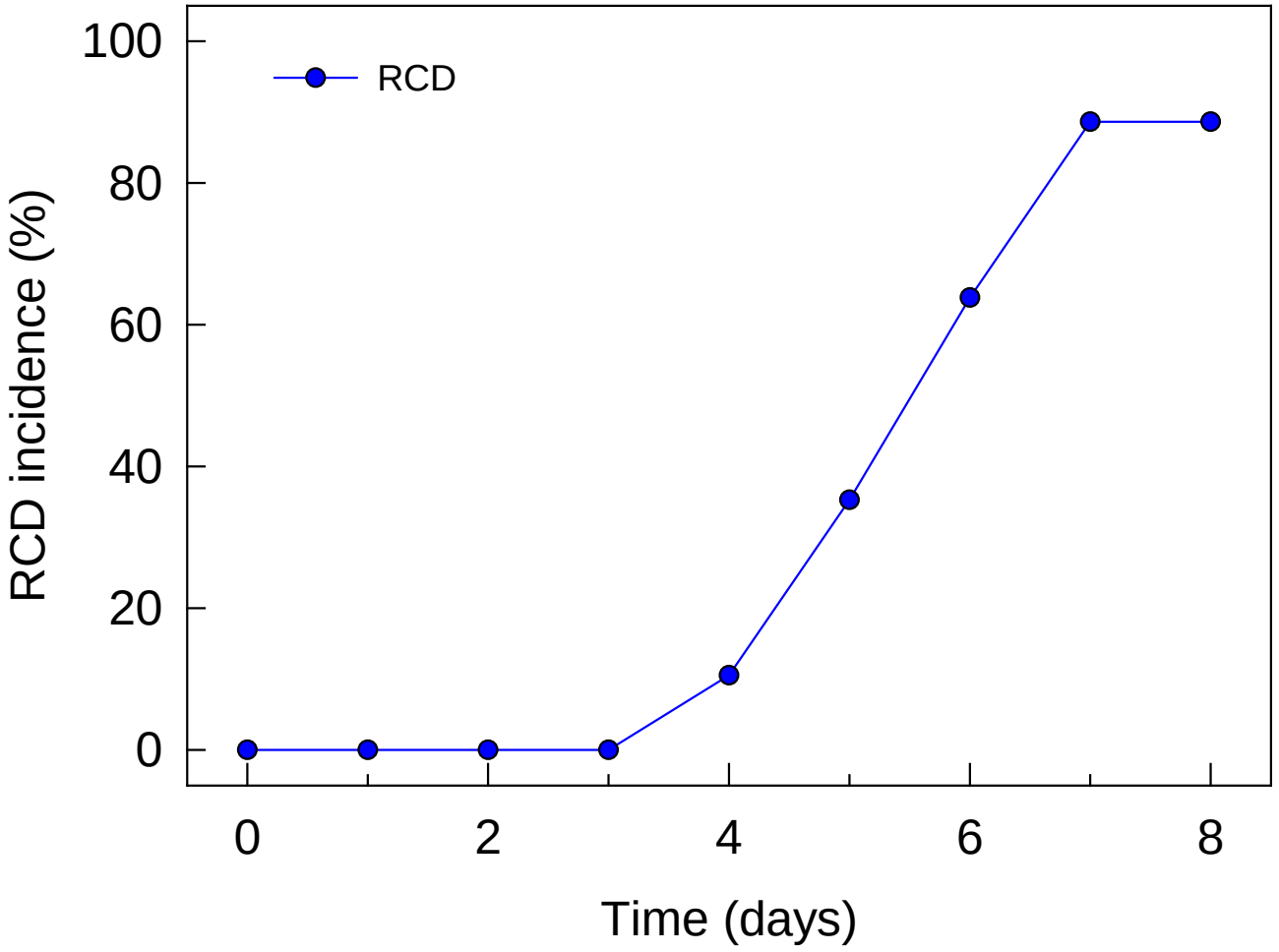
- 27 questionnaires were completed
- Considerable variation in on-farm management, picking, packing or transport was documented
- Anecdotal causes of RCD are many and varied
- Some farms with history of RCD were identified and assisted with the research activity

2. Standard assessment procedure

Objective

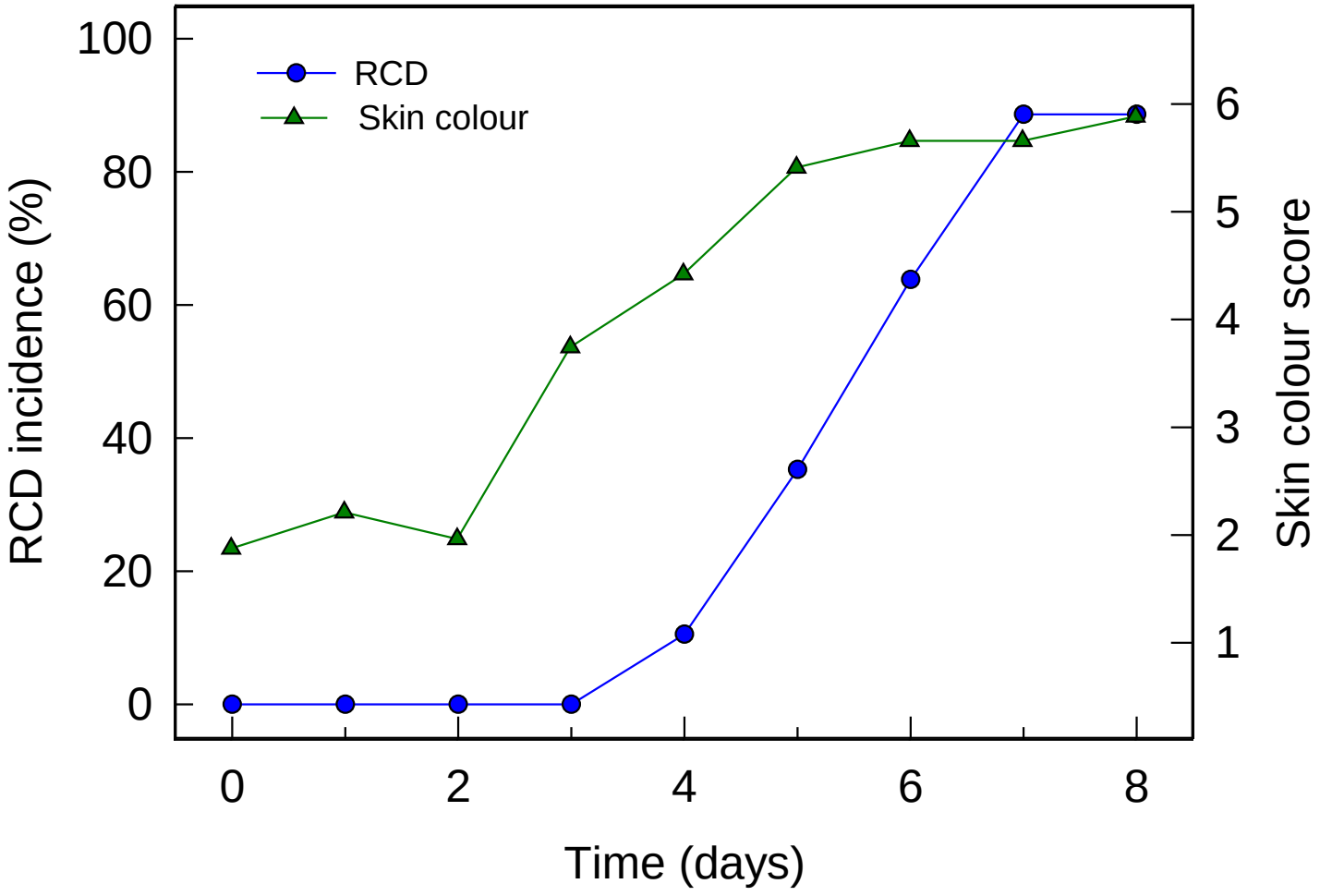
- Develop a protocol to accurately diagnose and rate RCD

2. Standard assessment procedure



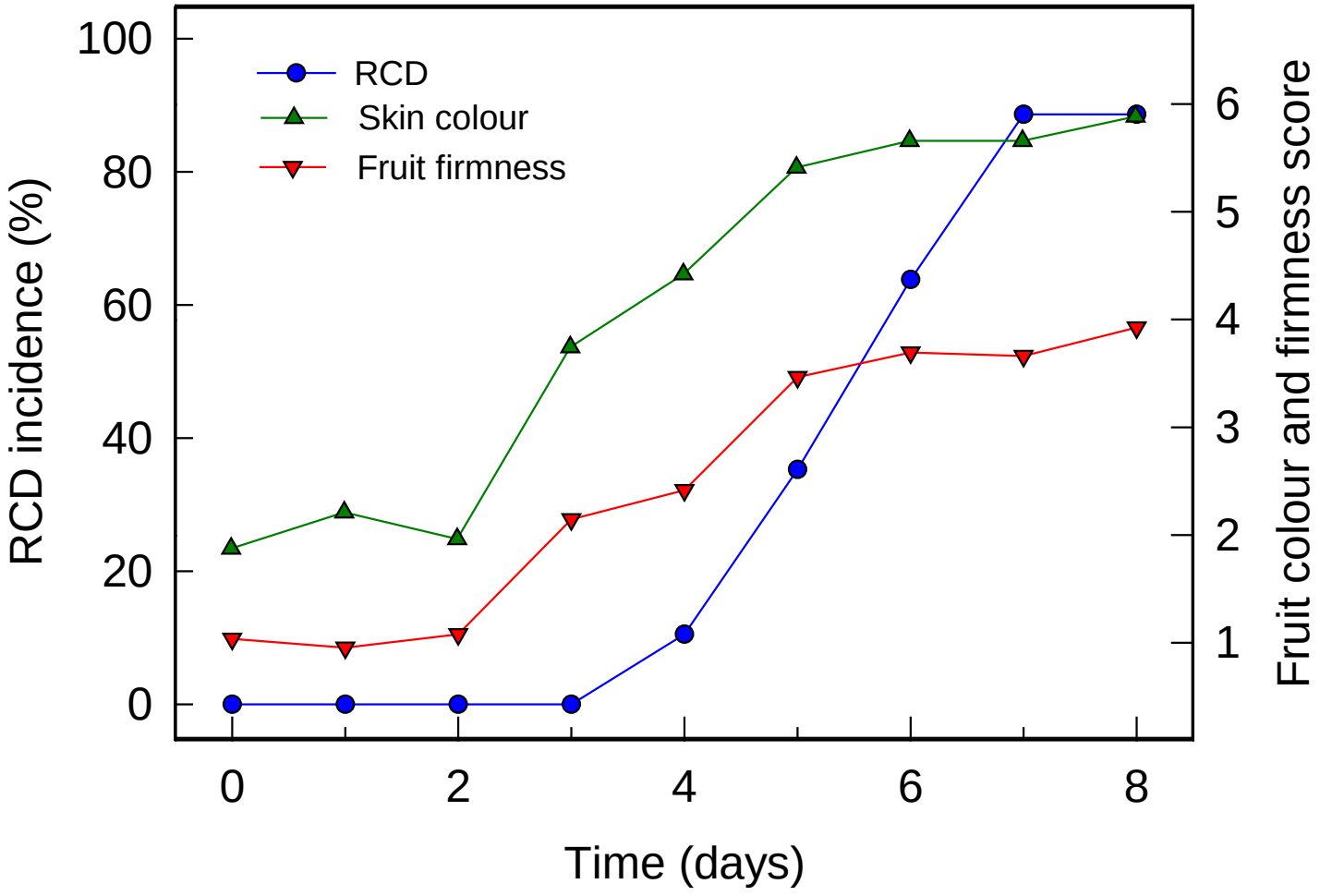
- Visible symptoms of RCD rapidly develop during ripening

2. Standard assessment procedure



- RCD reaches a maximum at the eating ripe stage

2. Standard assessment procedure



- RCD reaches a maximum at the eating ripe stage

2. Standard assessment procedure

0 -15%

15-30%

30-45%

45-70%

70-85%

85-90%

2. Standard assessment procedure

0-15%

15-30%

30-45%

45-65%

65-85%

85-100%

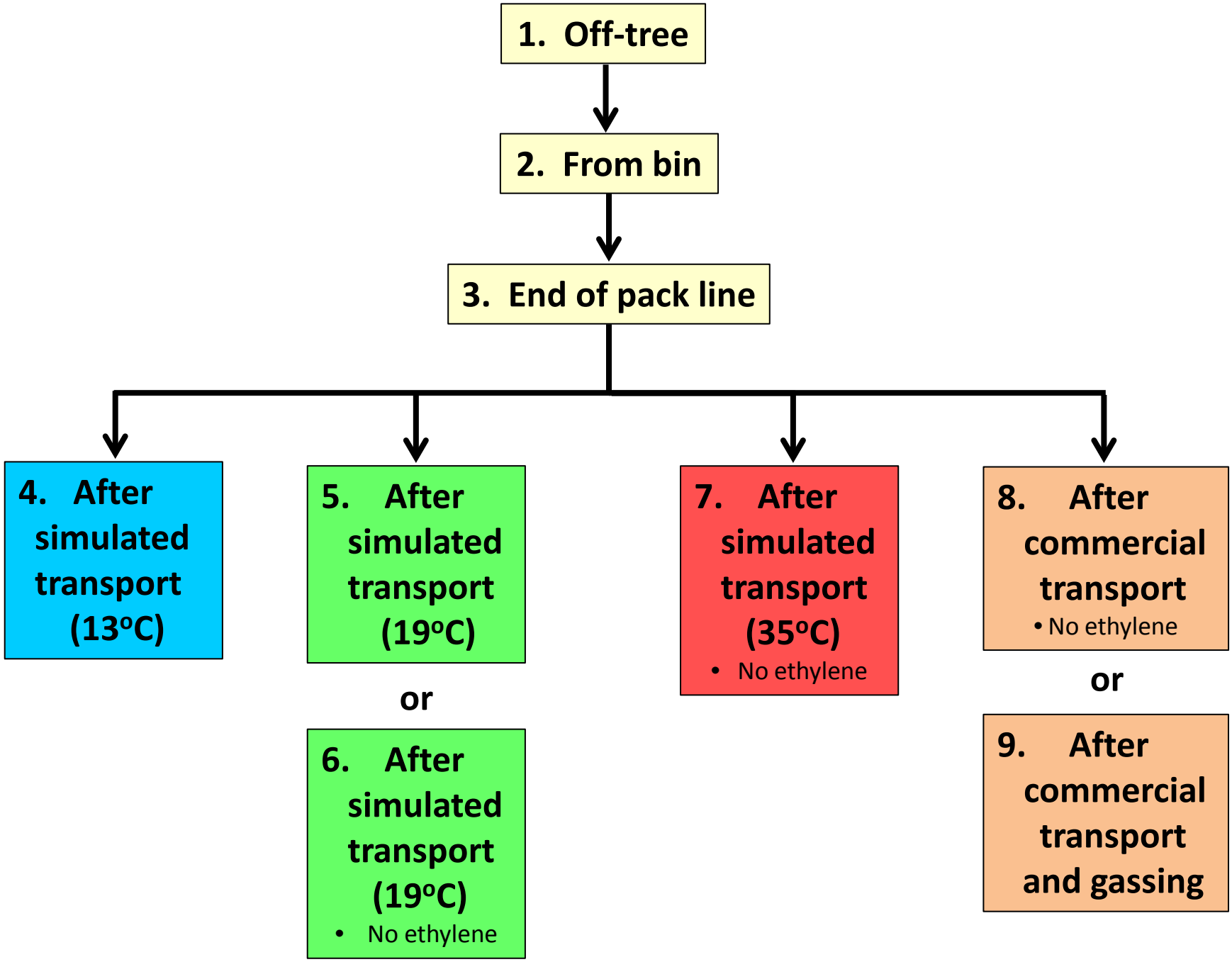
3. Sequential sampling trials

Objective

- Identify potential supply chain handling factors that may exacerbate the expression of RCD

Method

- Fruit were sampled from nine orchards
- Fruit were harvested at the commercial harvest date
- Tree, row and orchard block characteristics were documented
- Transport and ripening conditions were monitored


1. Off-tree
2. From bin
3. End of pack line
4. After simulated transport (13°C)
5. After simulated transport (19°C)
or
6. After simulated transport (19°C)
• No ethylene
7. After simulated transport (35°C)
• No ethylene
8. After commercial transport
• No ethylene
or
9. After commercial transport and gassing

3. Sequential sampling trials

RCD incidence (% of fruit affected by RCD)

Sampling step	F1	F2	F3	F4	F5	F6	F7	F8	F9
Off tree	15								
From bin	23								
End of pack line	20								
After commercial shipment	35								
After commercial gassing	**45**								

After simulated shipment 13°C	27								
After simulated shipment 19°C	41								
After simulated shipment 19°C	17								
After storage at 35°C	22								

3. Sequential sampling trials

RCD incidence (% of fruit affected by RCD)

Sampling step	F1	F2	F3	F4	F5	F6	F7	F8	F9
Off tree	15	45		28	4		2	0	
From bin	23	49		17	2		10	0	
End of pack line	20	39		23	15		2	52	
After commercial shipment	35	56		24	19		5	79	
After commercial gassing	**45**	**75**		**44**	**39**		**19**	77	
After simulated shipment 13°C	27	54		41	2		6	**85**	
After simulated shipment 19°C	41	50		27	14		6	38	
After simulated shipment 19°C	17	57		28	16		2	83	
After storage at 35°C	22	56		13	4		0	61	

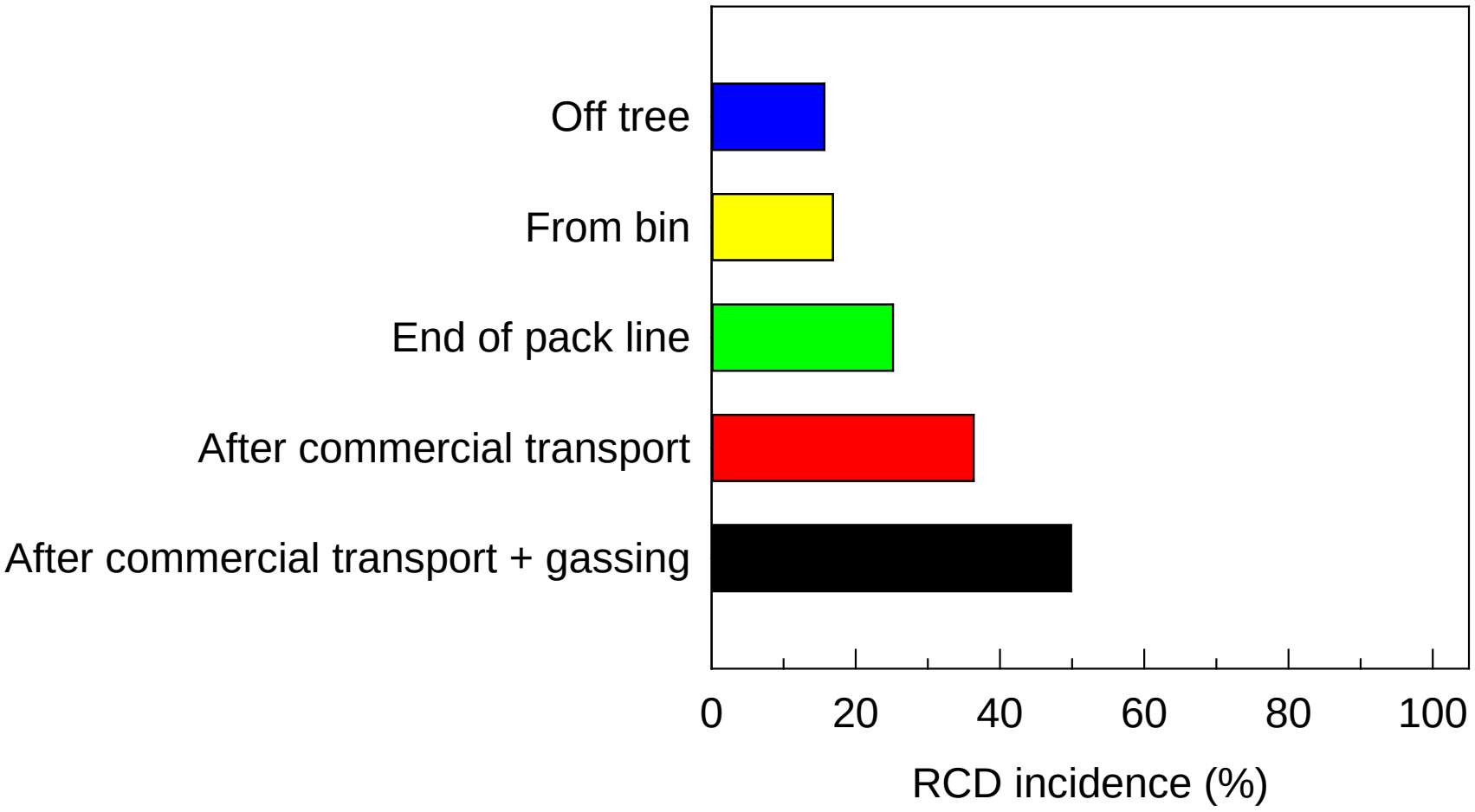
3. Sequential sampling trials

RCD incidence (% of fruit affected by RCD)

Sampling step	F1	F2	F3	F4	F5	F6	F7	F8	F9
Off tree			13			0			0
From bin			**52**			2			0
End of pack line			46			7			10
After commercial shipment			38			3			10
After commercial gassing			24			4			12
After simulated shipment 13°C			24			12			17
After simulated shipment 19°C			20			15			21
After simulated shipment 19°C			25			9			**26**
After storage at 35°C			15			**17**			7

3. Sequential sampling trials

RCD incidence (% of fruit affected by RCD)



3. Sequential sampling trials

RCD severity (Average % area of flesh with RCD)

Sampling step	F1	F2	F3	F4	F5	F6	F7	F8	F9
Off tree	9	20	20	11	2	0	8	0	0
From bin	10	16	4	6	10	2	5	0	0
End of pack line	6	11	18	5	3	5	1	11	7
After commercial shipment	19	**49**	**31**	17	18	45	**14**	34	14
After commercial gassing	**26**	27	19	**17**	**53**	**60**	9	**50**	6
After simulated shipment 13°C	11	18	10	9	1	13	2	11	4
After simulated shipment 19°C	6	24	6	10	5	19	1	9	3
After simulated shipment 19°C	9	12	6	9	2	1	1	23	**15**
After storage at 35°C	15	11	8	8	3	3	0	4	11

3b. Additional trials

- Time of day (7:30 am vs 4:00 pm)
- Treatment with copper
- Hot water dip
- Antimicrobial treatments
- High CO_2
- Cross contamination in the packing line
- Condensation on fruit
- KNO_3

Difficult to demonstrate response because we did not know prior to the experiment if RCD existed on the farm

3b. Additional trials

- Effect of rain on RCD incidence

2013 season (Lambells Lagoon, NT)

		Skin		Flesh	
Harvest time	**Dry matter (%)**	**Incidence (%)**	**Severity (%)**	**Incidence (%)**	**Severity (%)**
12 h after rain	14.4	46	57	68	59
60 h after rain	14.6	32	35	47	38

2014 season (Mareeba, Qld)

Harvest time	Pre-cooling temperature	Shipment temperature	Shipment CO_2 level	Skin RCD (%)	Flesh RCD (%)
Before rain	14^{o}C	14^{o}C	0.1%	15	29
After rain	14^{o}C	14^{o}C	0.1%	35	69

3b. Additional trials

•Effects of harvest maturity on RCD

		Skin		Flesh	
Harvest #	**Dry matter (%)**	**Incidence (%)**	**Severity (%)**	**Incidence (%)**	**Severity (%)**
1	12.7	49	52	66	57
2	14.6	30	36	43	39
3	16.9	32	17	47	18

- RCD was highest for fruit picked early
- Disease was observed in 40-80% of fruit with RCD

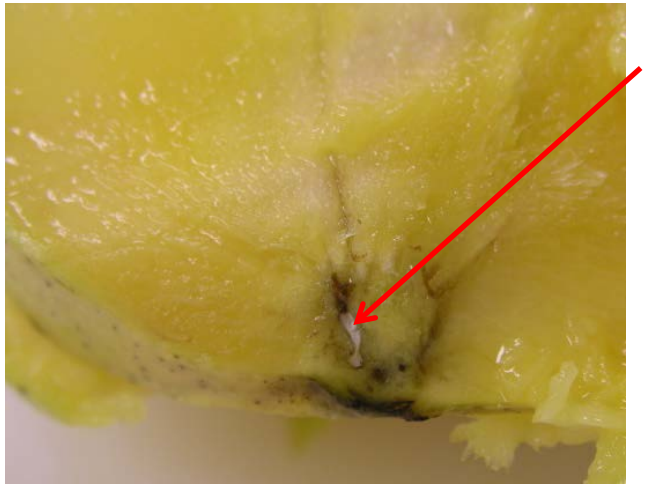
3b. Additional trials

Effect of storing fruit in air-tight bags for 3 days

	% of fruit with RCD		% of fruit surface with RCD	
Storage temperature	20°C	30°C	20°C	30°C
Control (No bag)	11	22	1	2
Sealed control	67	78	10	20
Sealed + moisture	78	89	27	39
Sealed + CO_2	78	89	22	38
Sealed + moisture + CO_2	100	100	16	22

4. The role of bacteria?

- Two bacterial organisms were isolated from RCD-affected KPs
  - *Enterobacter* sp. and *Pantoea* sp.
- These bacteria were not recovered from fruit without RCD

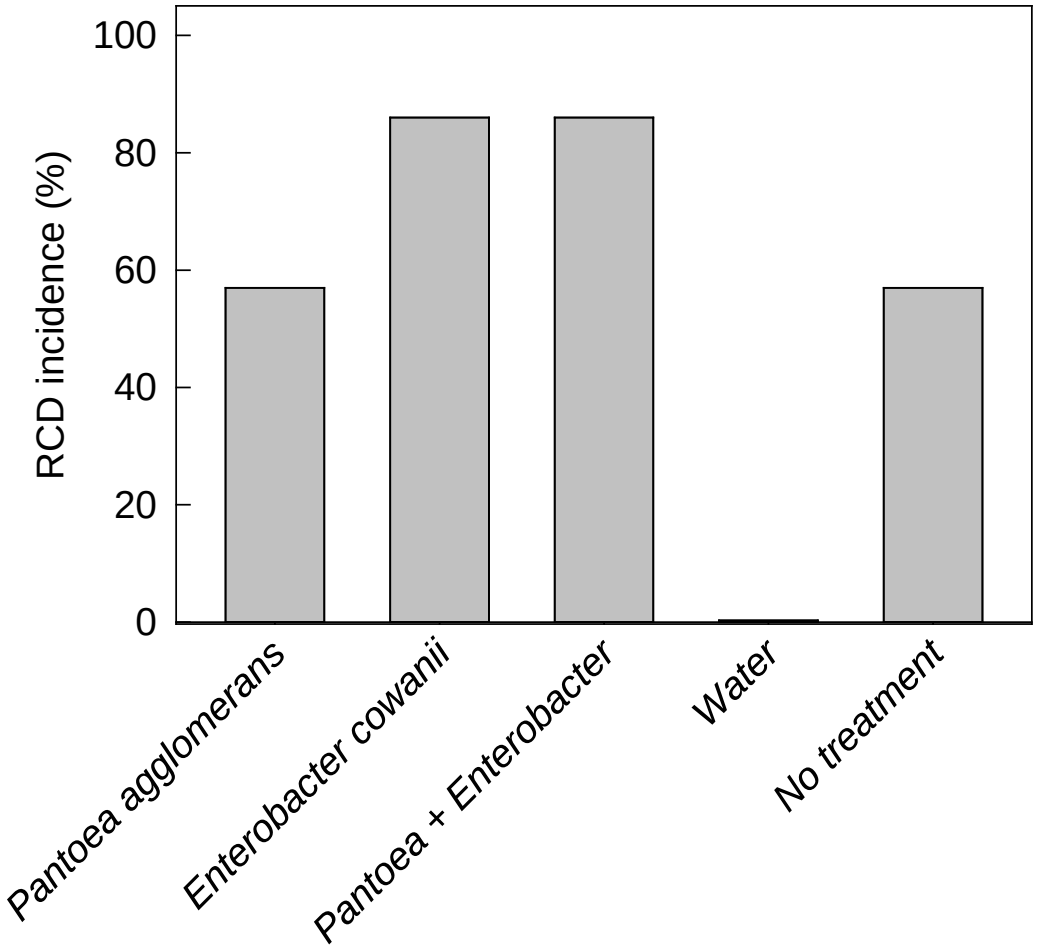


White colony

Decayed tissue

4. The role of bacteria?

- Green mature fruit were inoculated with each bacterial species and incubated until ripe



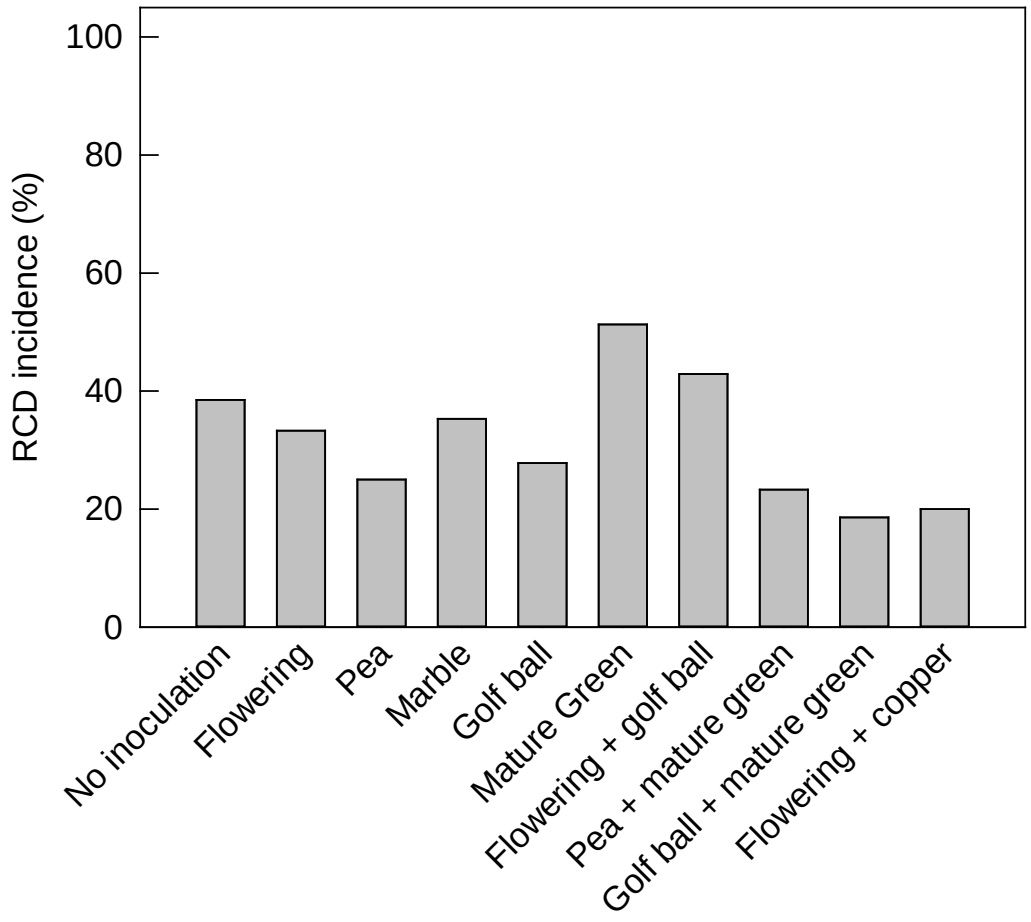
Field trial – inoculating fruit

- KP mango flowers and fruit were inoculated with *Pantoea agglomerans* at different growth stages
  - Flowering (before anthesis)
  - Pea
  - Marble
  - Golf ball
  - Mature green
  - Flowering + golf ball
  - Pea + mature green
  - Golf ball + mature green
  - Flowering + copper sprays
  - No inoculation

Spray inoculation

Sandpaper injury
+ spray inoculation

Incidence of RCD in inoculated fruits

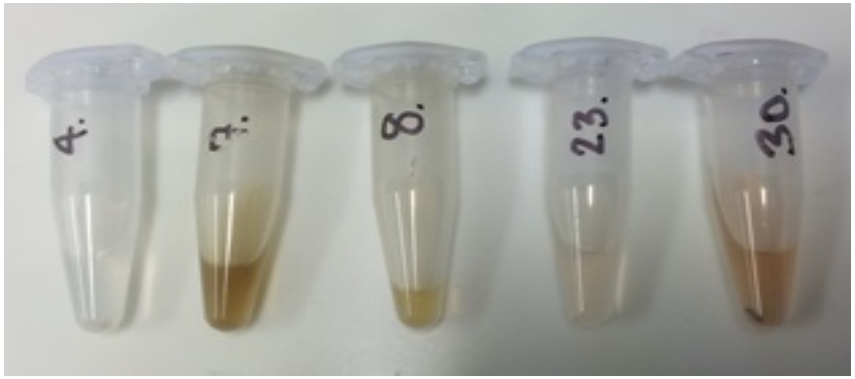


- No clear effects of inoculation on RCD
- Fruit with no stem end rot had less RCD

Water sampling

- Samples of mango wash/water from harvest aids were collected
- Samples of dump water from sheds were collected
- The samples were tested for bacteria, including *Pantoea*

Water sampling



The number of bacteria present in mango solutions and RCD % at end of the chain

Farm	Water rinse	Mango wash	Shed dump water	RCD %
1	2 billion*	0	0	46.5
2	4.3 billion*	1.9 billion*	2.2 million	70.6
3	-	3.5 billion*	5.6 million*	24.1
4	-	3.2 billion*	4.9 million*	44.0
5	-	4.9 billion*	1.0 billion*	38.8
6	-	3.6 million*	0	4.3
7	-	9.0 million*	0	19.0

* Denotes presence of *Pantoea agglomerans*

Effect of hot water treatment

Water treatment	Inoculated?	% RCD incidence	% RCD severity
30°C, 5 minutes	No	92	54
30°C, 5 minutes	Yes	100	56
52°C, minutes	No	42	43
52°C, minutes	Yes	33	30

What have we learnt so far about RCD?

1. RCD incidence can vary between farms and harvest dates
2. RCD can be found in green fruit with injury or infection
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Towards managing RCD

Preliminary recommendations

- Follow best mango production and handling practices
  - Limit stress on trees and fruit
  - Harvest at correct fruit maturity
  - Practice good orchard and shed hygiene
  - Pre-cool and transport fruit at recommended temperatures
  - Keep documented records of any RCD occurrence

Future research

We need to understand how to prevent shipments arriving in the market like this

Future research

Possible steps

- Complete retail survey to determine extent of RCD
- Compare best vs existing practice on high risk farms to better understand the cause and control of RCD
- Assemble a team to rapidly respond to outbreaks

Acknowledgements

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