Cold chain guidelines

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Chilling injury roulette at the cold store

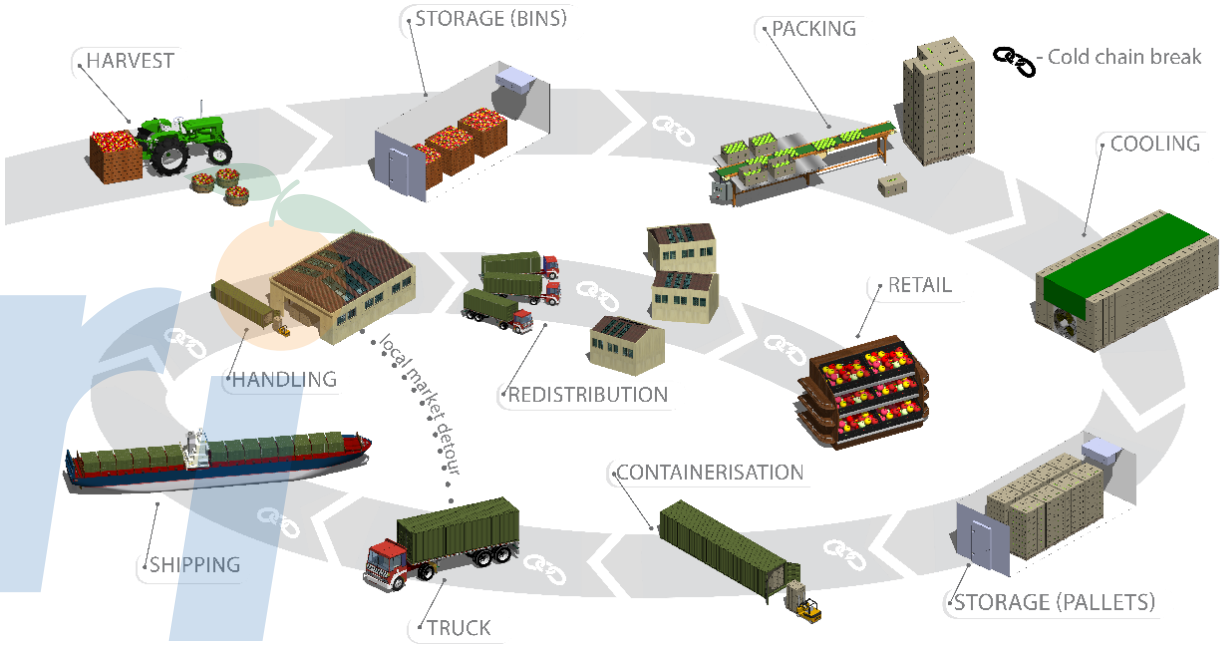
- **Chilling injury:** Cold store handling is the primary determinant of chilling injury (CI) development, which can progress from healthy fruit to severe surface pitting.

- **Logistical drivers:** Current procedures are largely dictated by throughput and market access requirements rather than fruit physiology.

- **High risk:** This logistics-first strategy is significantly increasing citrus susceptibility to cold chain damage.

Role of precooling

- Accelerated cooling
  - Increased fruit throughput at cold store
  - Reduce respiration rates
  - Inhibit decay
  - Market access requirements



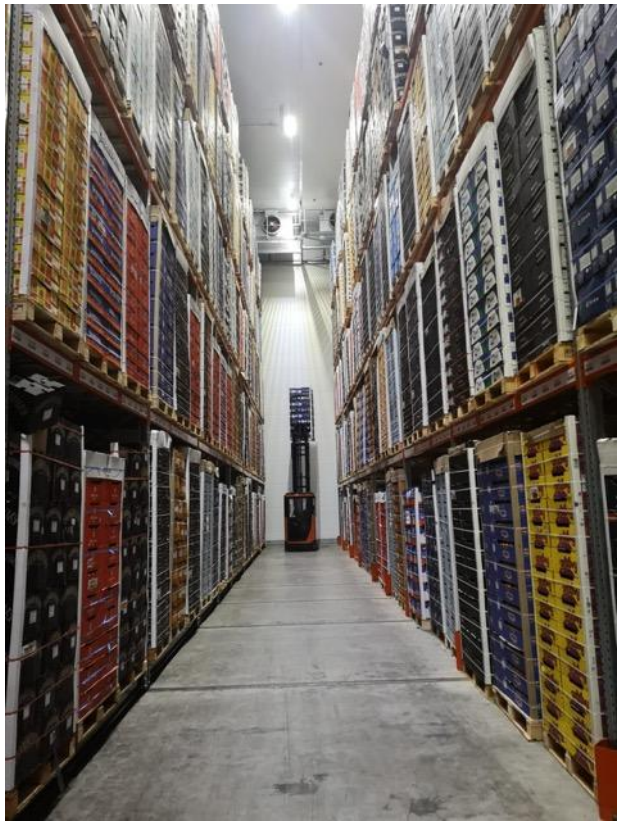
- In-transit cold treatment markets
  - Required for market access compliance
  - Enforced through immutable bilateral agreements
  - Precise precooling and in-transit temperature monitoring

- EU oranges
  - As of 1 Jan 2023: All oranges to the EU must be cooled to setpoint
  - Previously, oranges only had to be cooled to 5 °C
  - Static cooling will not be sufficient

Precooling types

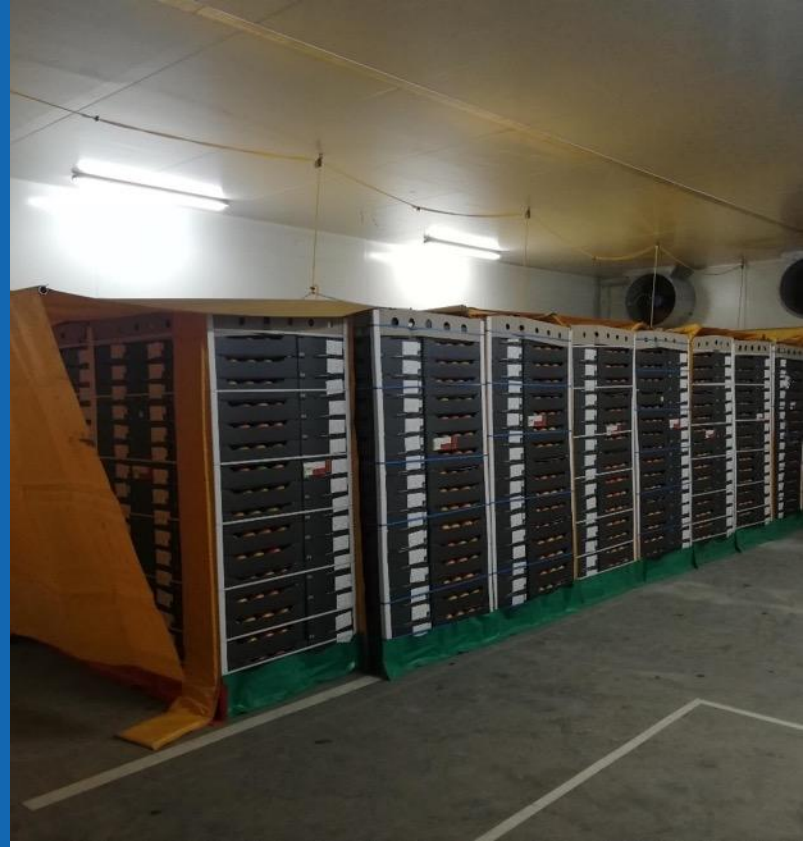
Static cooling

- Cooling fruit without a tunnel or airflow
- Standard cold room
- Low cooling rates



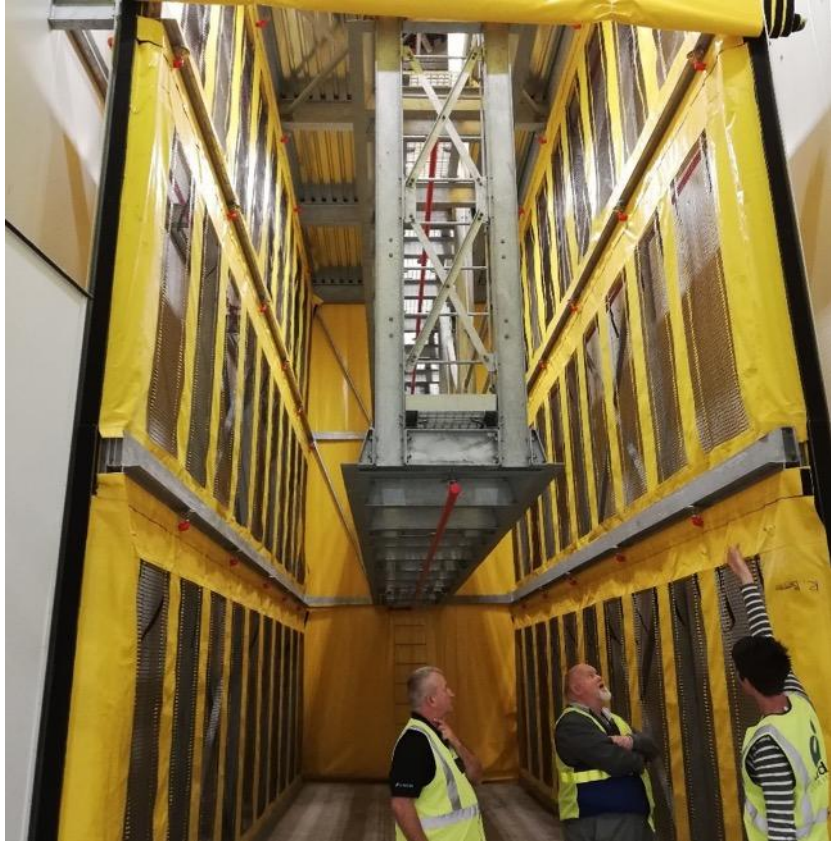
Forced-air cooling

- Specialized tunnel
- High cooling rates



Tarp FAC

- Dedicated or temporary (mobile) setups
- Usually a single layer (vertical)
- Fan/s on side
- More control possible



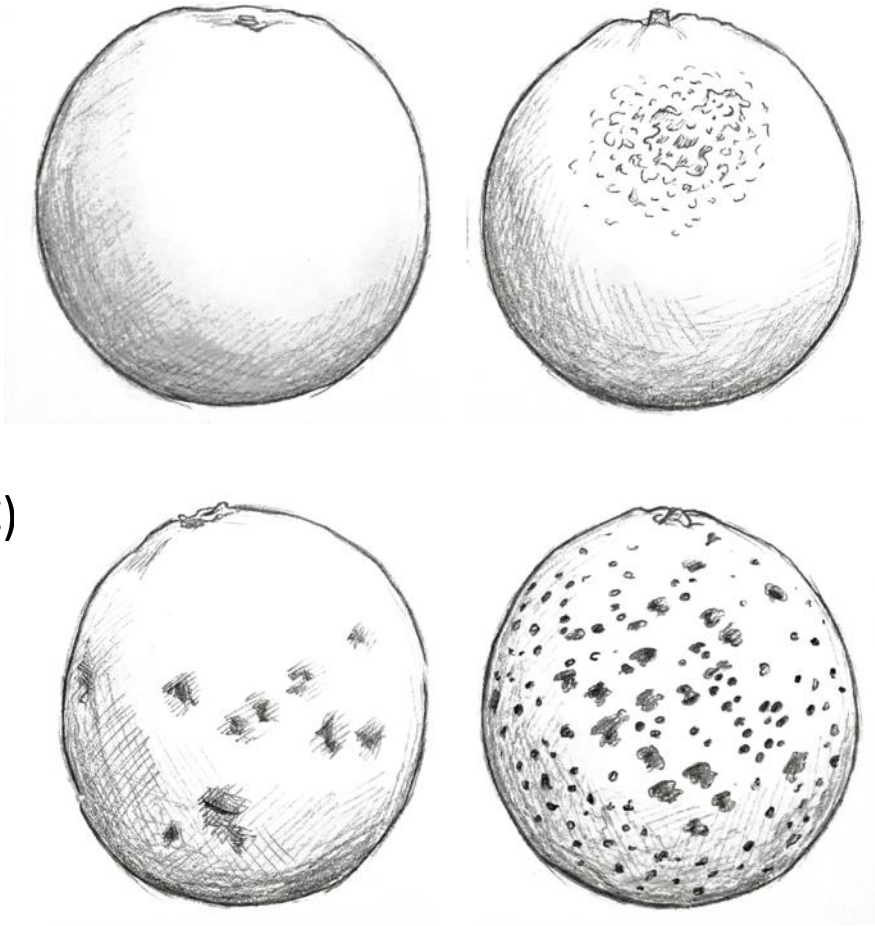
Racking FAC

- Dedicated setups
- Multiple levels (vertical)
- Higher throughputs
- Fan/s on top
- Less control and higher opportunities for errors

Forced-air cooling

Cold store challenges?

- Too fast
  - Freeze damage (<-2 °C)
  - Chilling injury
    - Often only visible at market
    - Cool rate and duration under critical temperatures (< 2°C)



- Too slow
  - All oranges to the EU must be cooled to set-point (instead of 5 °C)
  - Limited cold storage infrastructure
  - Cold stores will be forced to push fruit through system
  - Faster cooling = higher cold store throughputs

- Precooling musical chairs
  - Moving pallets in and out of precooling
  - Risk of decay (condensation)
  - High VPD (rind disorders)

Cold stores types

- Generalised view of cold store designs and operational strategies
- Some cold stores are a combination of these.

	Forced-air cooling dominant	Static cooling dominant
Modular Storage	Setup focuses on multiple small-scale FAC rooms, often supplemented by one or two larger rooms to handle varying batch sizes.	Utilises numerous small, independent rooms that rely on natural convection or low-velocity air rather than forced-air systems.
Monolith Storage	A few, massive cold rooms integrated with large-scale forced-air infrastructure to treat hundreds of pallets simultaneously.	A few very large "bulk room" volumes designed for high-density storage without internal FAC partitions or high-velocity airflow systems.

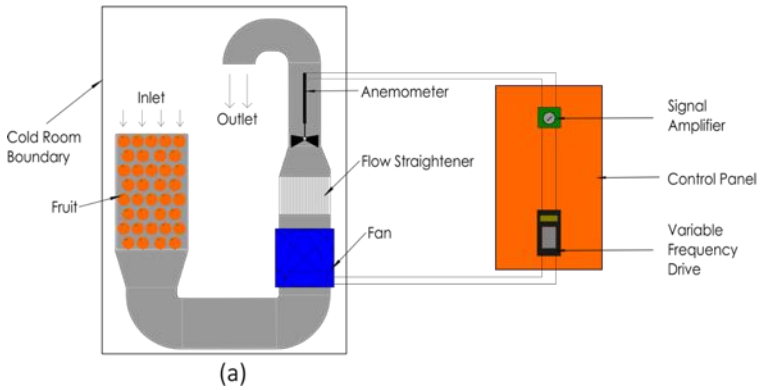
Grower/exporter relationship with cold stores

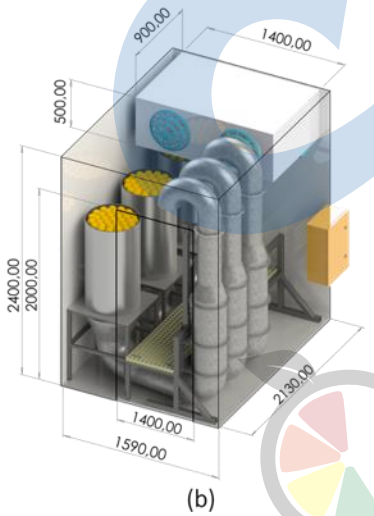
- Handling procedures (cold store)
  - Largely unspecified
  - If specified, unregulated
  - Minimal transparency
- Full transparency is required
  - Conditions and durations prior to cooling
  - Conditions and movements during static cooling
  - Conditions (air, pulp and RH) during precooling
- If you don’t see what’s going on:
  - No liability
  - Can’t identify trends
  - There are trends!

Implement agreements to mandate responsibility and consequences

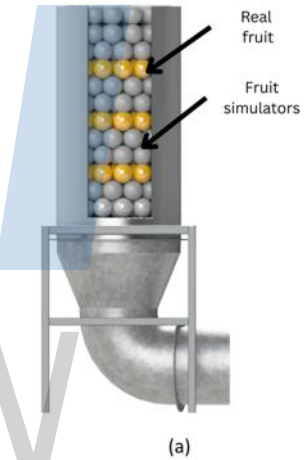
2025 findings

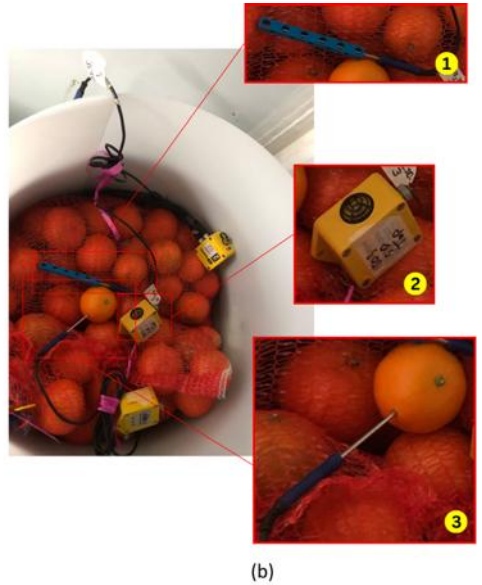
- Huge trials performed over 2024 and 2025
- Laboratory wind tunnel to simulate true commercial cold chain conditions





Cooling tunnel with overall dimensions and specialised parts shown. Parts indicated: (1) Anemometer mount. (2) Anemometer assembly and exhaust duct stay. (3) Exploded view of anemometer mount assembly. (4) Orifice plate with detailed dimensions and flow direction indicated. (5) Star-type flow stabiliser. (6) Test section with cut-away to show internal parts. (7) Close-up view of test section bottom end. (b) Ducting assembly with general dimensions.

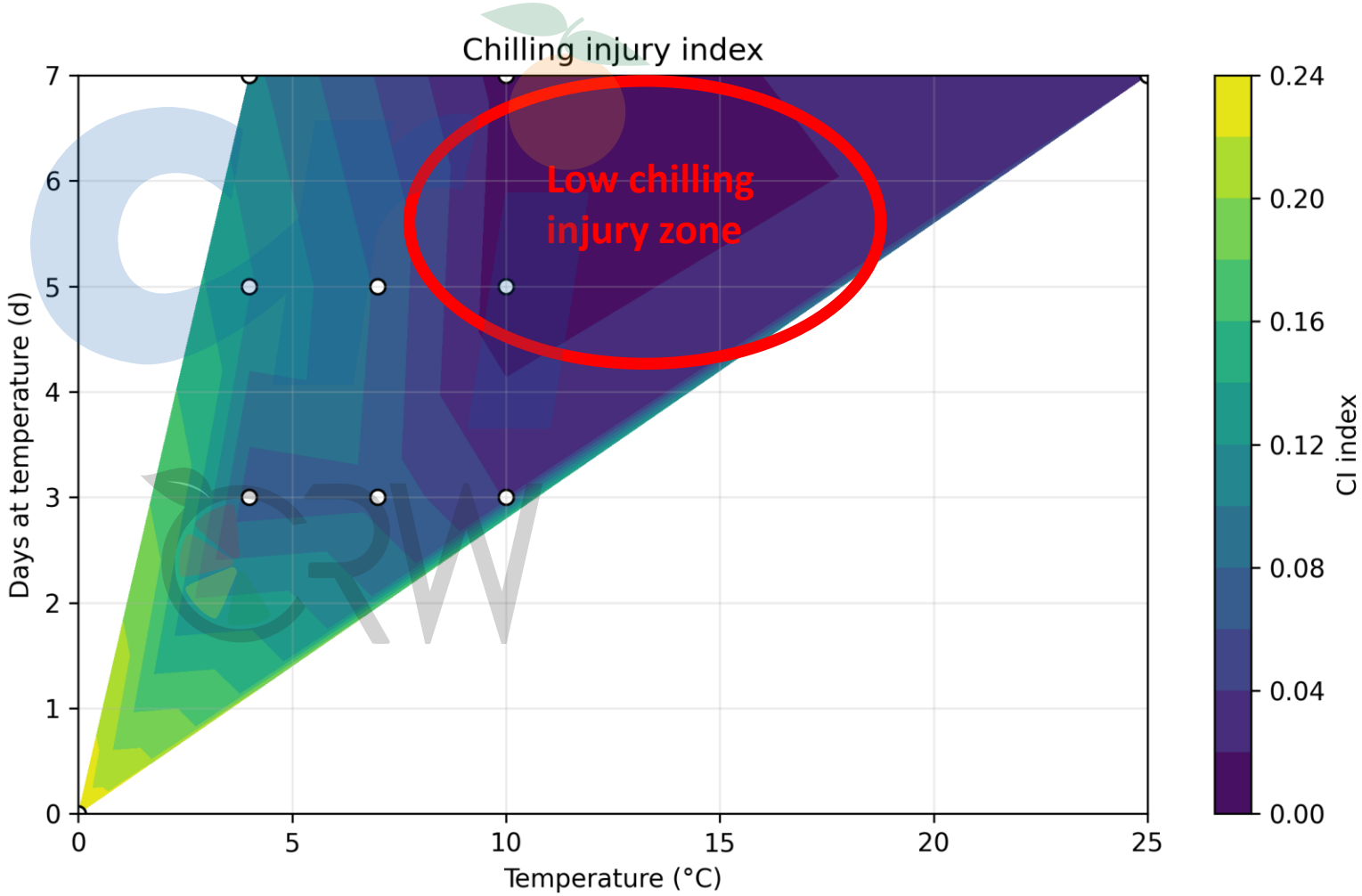




Trial preparation: (a) Fruit test section illustration with cut-away to show real-to-simulated fruit arrangement. (b) Photos showing sensor placement for every fruit level in a cooling tunnel during trial preparation, highlighting the following: (1) Thermistor probe with isolation cover fitted. (2) RH sensor placement. (3) Pulp temperature probe placement.

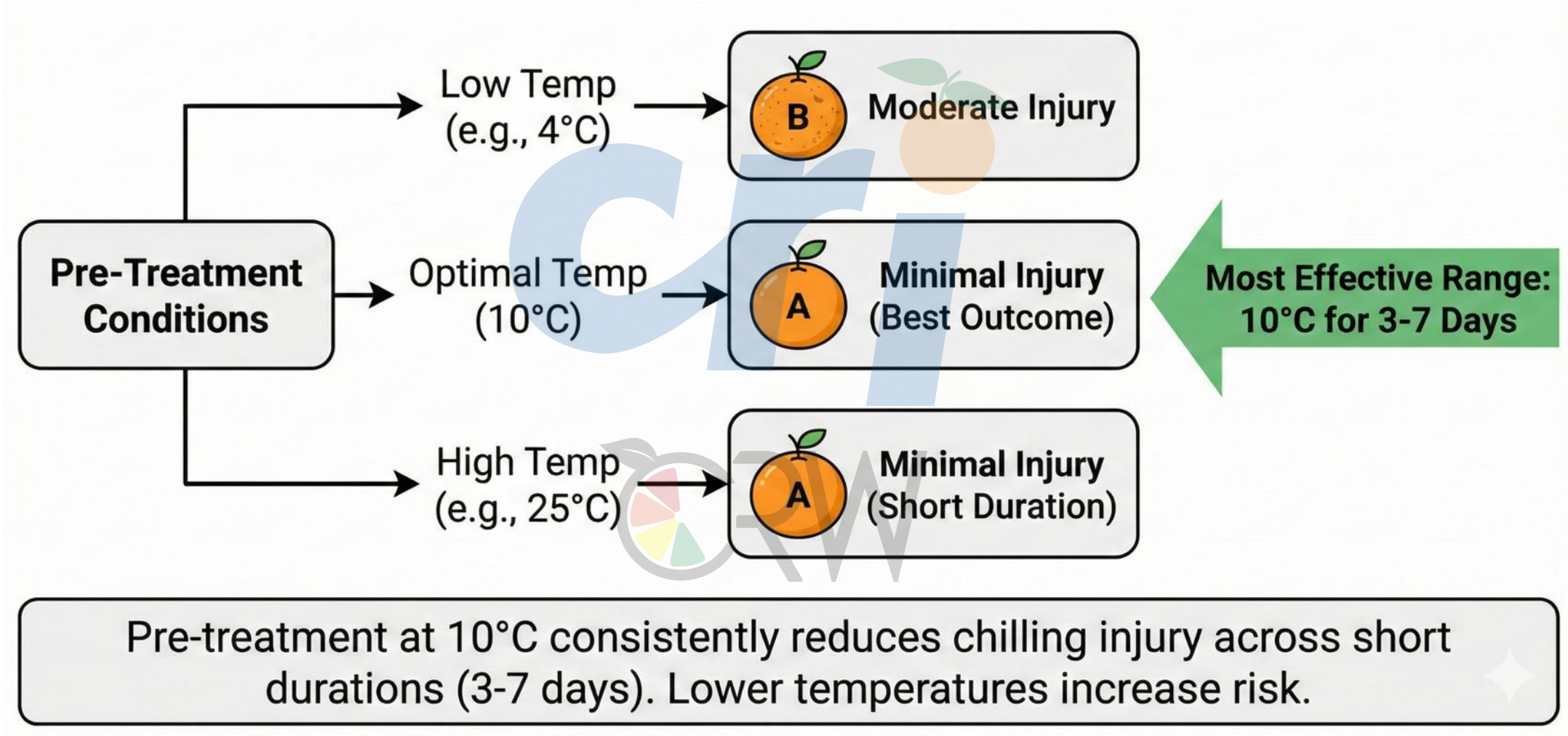
Preconditioning reduces chilling injury susceptibility

- Low-temperature conditions before precooling are important!
- 5 day at 10°C - 15°C is optimal
  - Based on one pilot study
  - More work to come



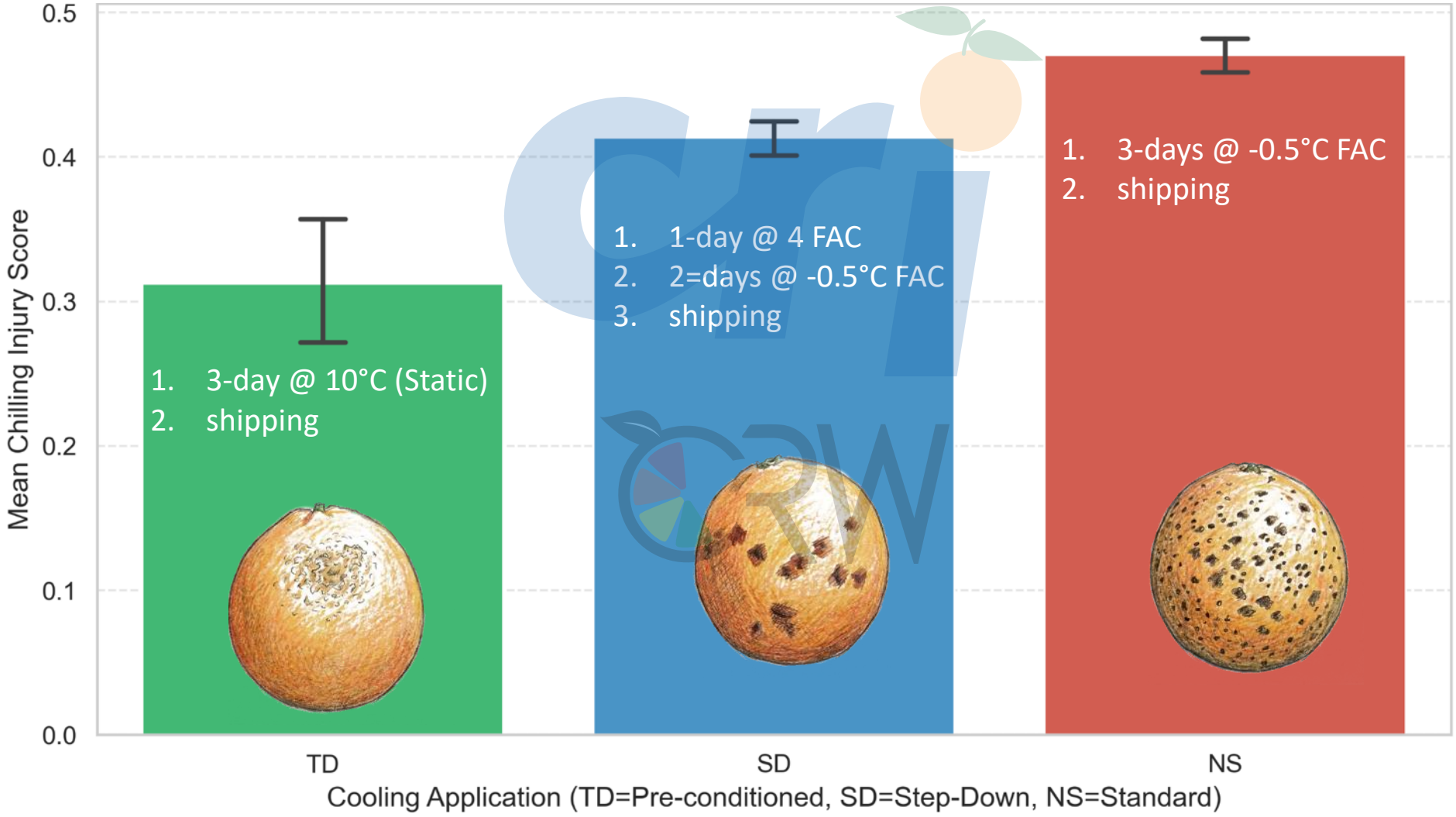
Lesson 1:

Preconditioning reduces chilling injury susceptibility



Recommendations: Step-downs

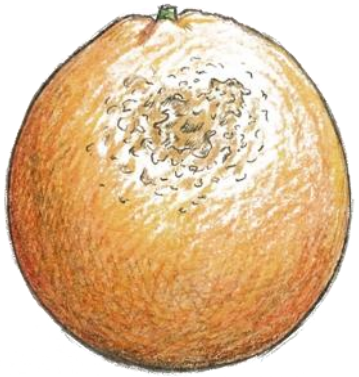
- Gradually stepping down the fruit during precooling significantly reduces chilling injury



Lesson 2:

Recommendations: 10 °C holding

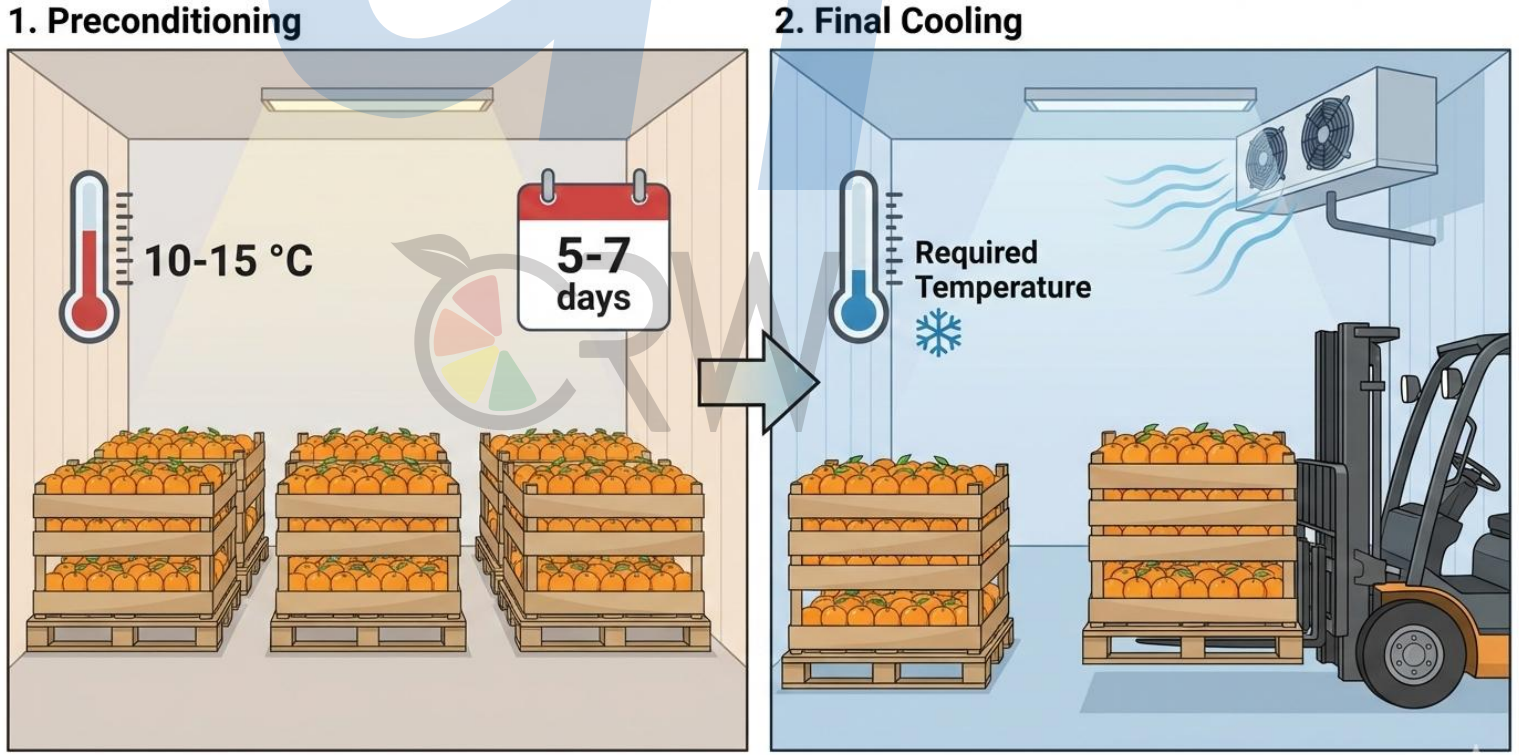
Static cooling approach



Low damage risk

Two-room approach

1. Place fruit in a static room at 10-15 °C for 5-7 days
2. Move the pallet to new room to be cooled to the required temperature



Recommendations

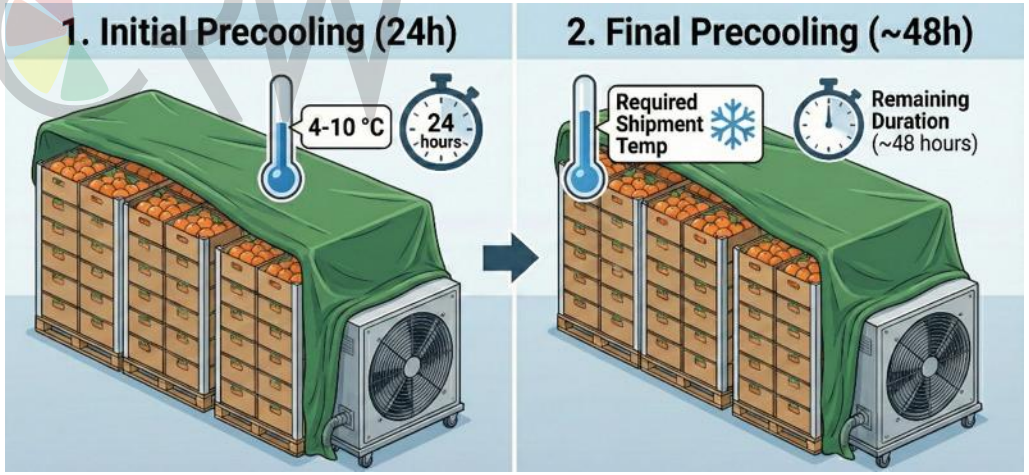
FAC cooling approach

Moderate damage risk

<u>Step-down approach</u>

1. Optional: Place fruit in a static room at 10-15 °C for 5-7 days
2. Place fruit in tunnels and precool fruit to 4-10 °C for 24 hours
3. Continue precooling to the required shipment temperature (remaining duration)

- Apply low pressure drops during FAC (30-50 Pa)
  - Experiments show a clear reduction in chilling injury when combining low airflow rates and step-downs.



Recommendations

FAC cooling approach

High damage risk

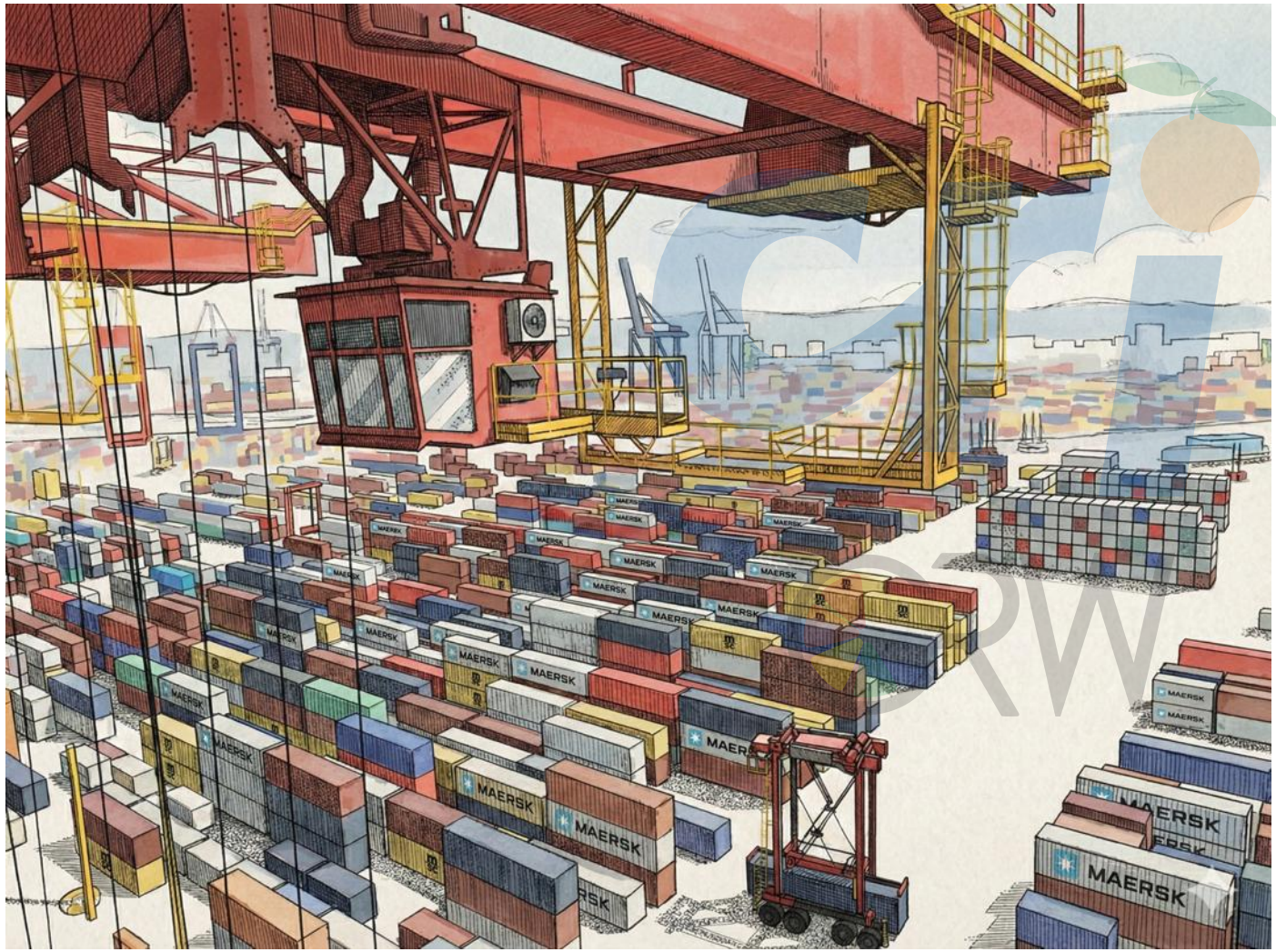
<u>Direct cool approach</u>

Not recommended!

1. Place fruit in tunnels and precool (FAC) fruit to setpoint

- Apply high pressure drops during FAC (~100 Pa).
  - When precooling without stepdown, there is a slight reduction in chilling injury when applying higher flow rates – higher fan speeds
  - i.e. Reduce the duration of large VPD, as soon as possible

Container and pallets



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Chilling injury and container shipping

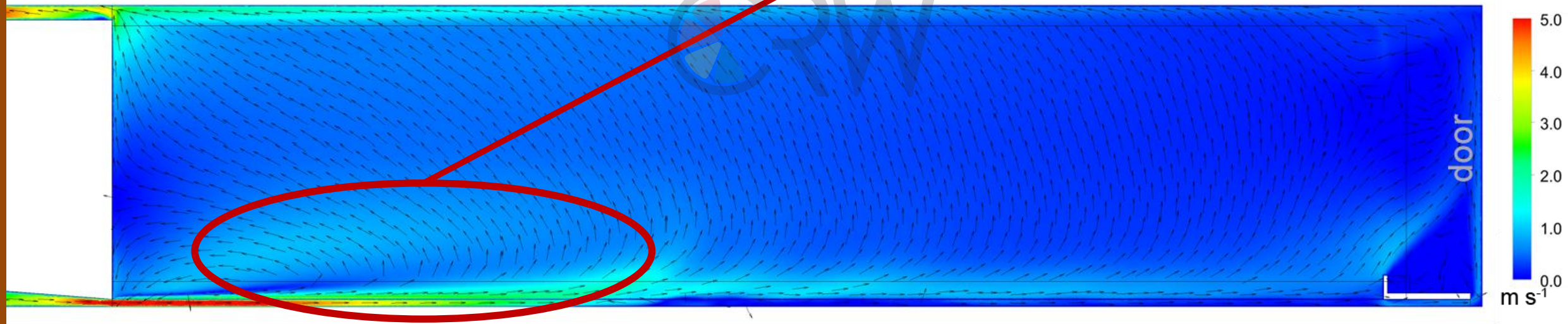
Chilling injury is a factor of multiple factors

- Low temperatures + duration
- High air velocities

- Citrus is at the highest risk for chilling injury at the container chill zone

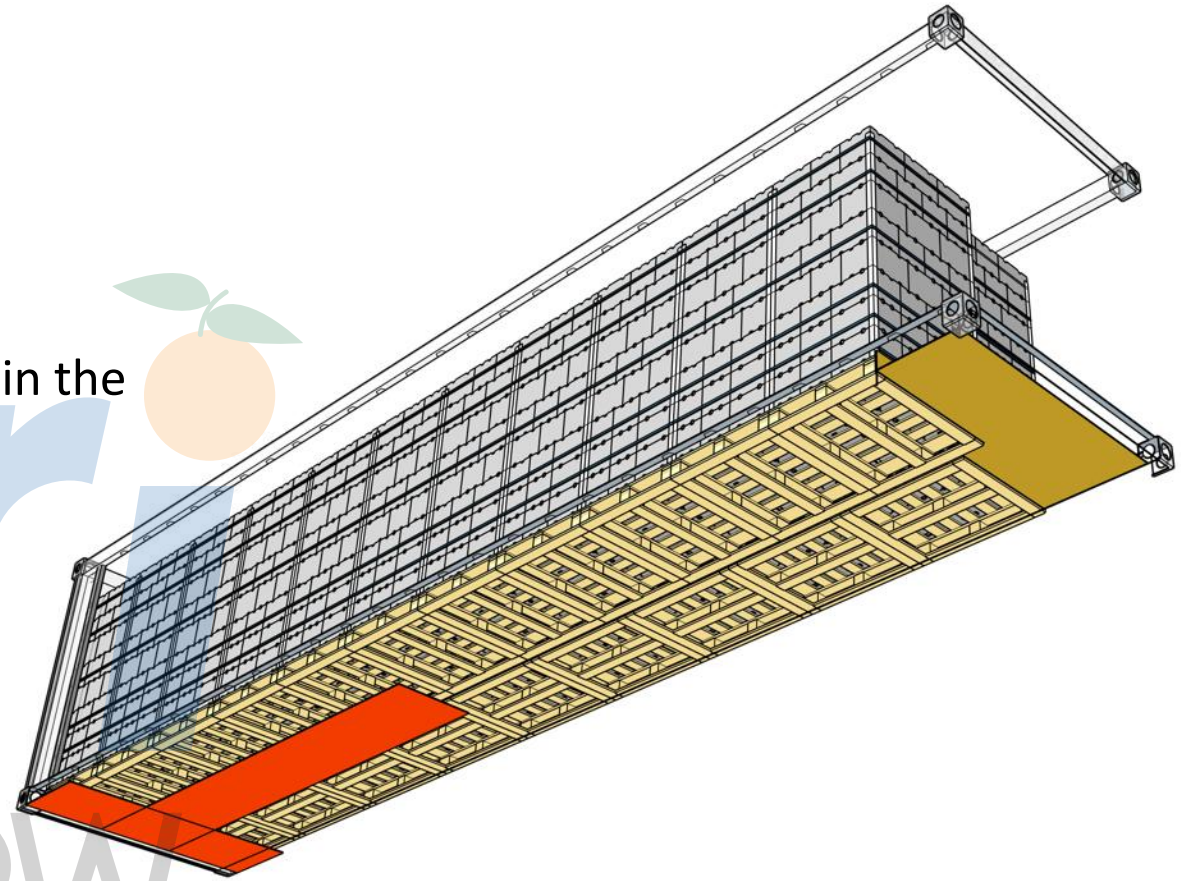
Container chill zone

Chilling injury risk zone



T-Floor

- Manufacturing support
  - Anyone can manufacture
  - Reefer mat EasyCO (mike Cohen) make a good product
- Experimentally proven to create more uniform cooling in the container
- Improves cooling near the door



easyCO & Wave Paper

Reefer Mat™ Sales Brochure

Contact us

Mike (+27) 826 5555 00 — mike@easyco.co.za

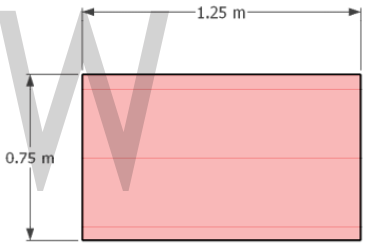
Andy (+27) 83 251 9169 — andrew@wavepaper.co.za

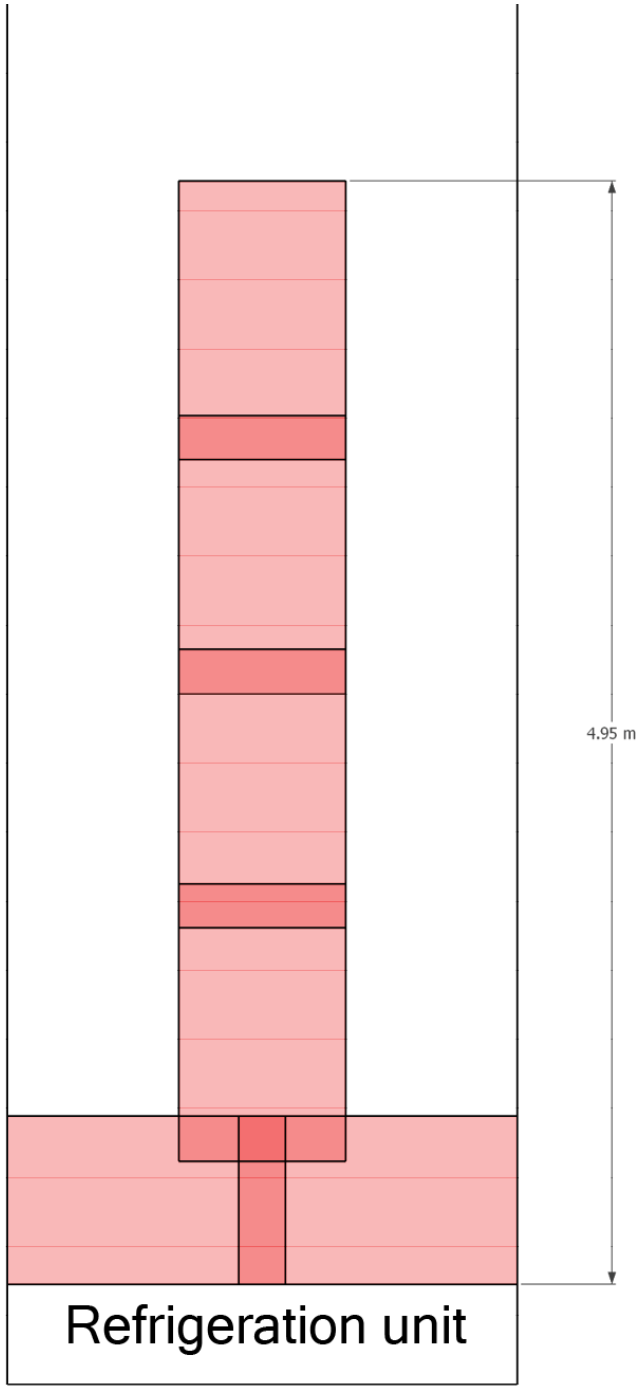
Local stock available for rapid dispatch across Southern Africa and beyond.

T-Floor

- Manufacturing support is requested from corrugators

- It can be manufactured from anything
  - Highly robust
  - single-wall corrugated board
  - Liner board

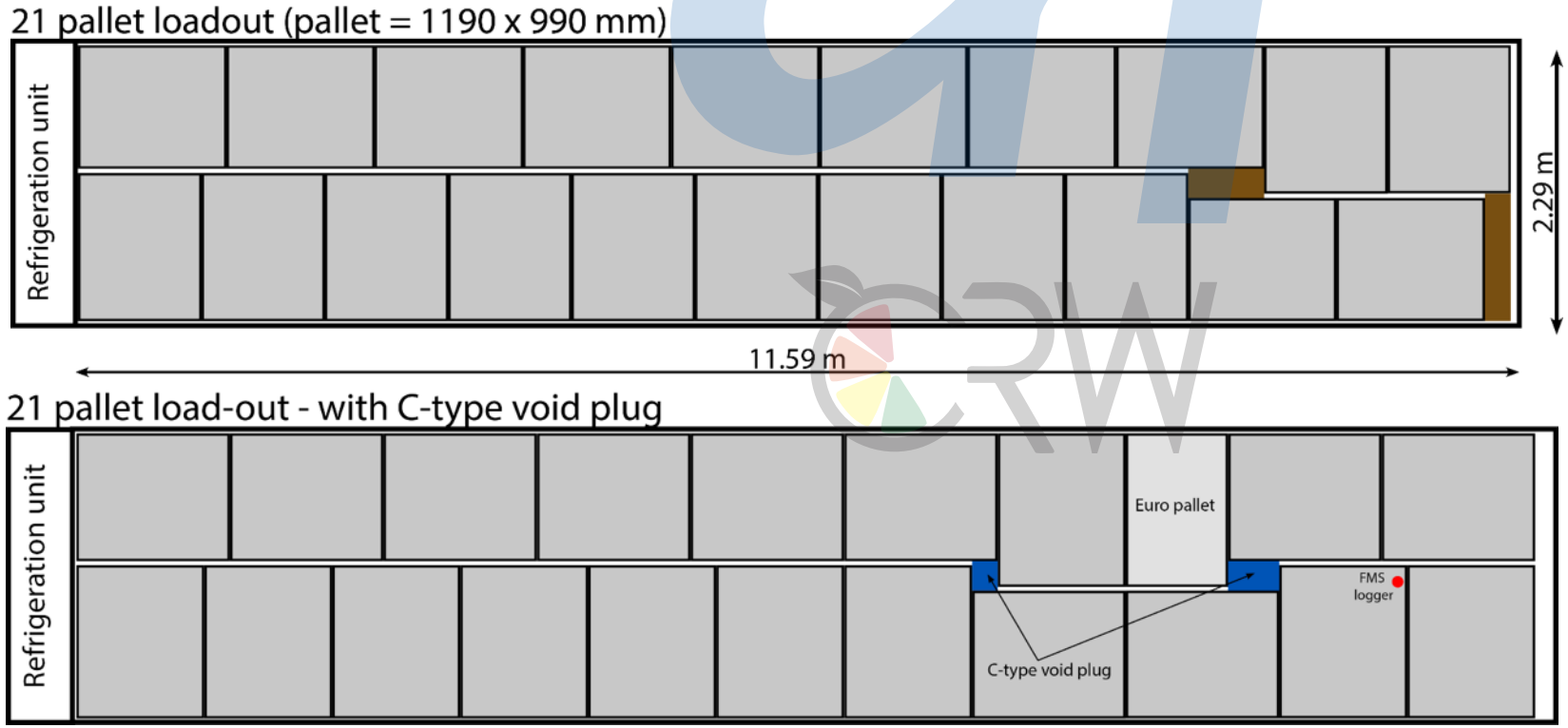




21 Pallet load-out

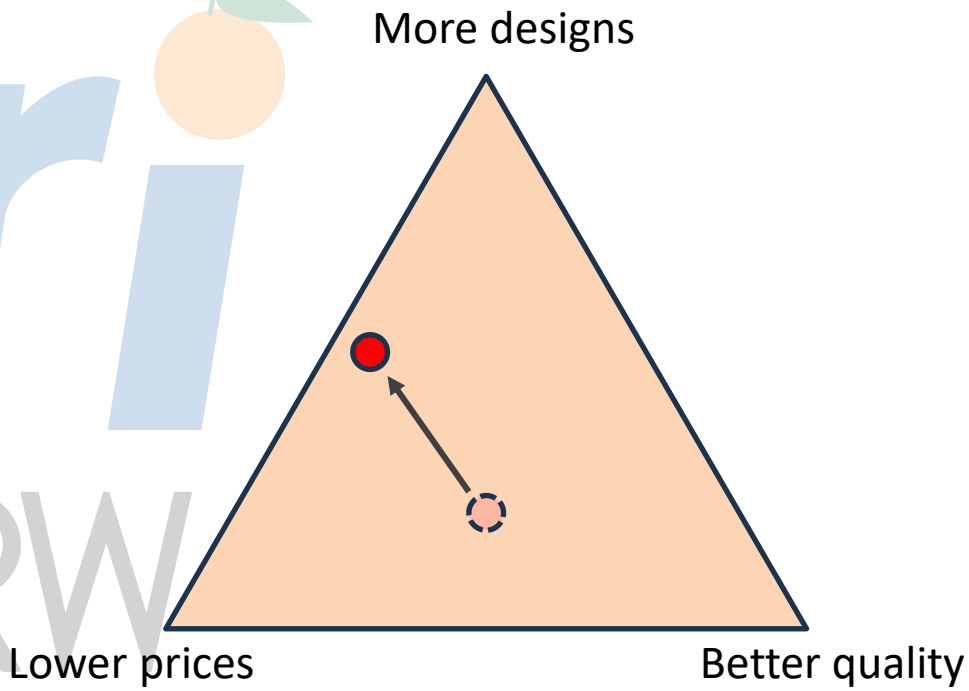
- Many reports of 21 pallets not fitting into container
  - Depends on the container design (some longer than others)
- Cold stores are not installing the void plugs.
  - Because they often can not
- This could be a challenge in future.

Feedback please



Pallet bases

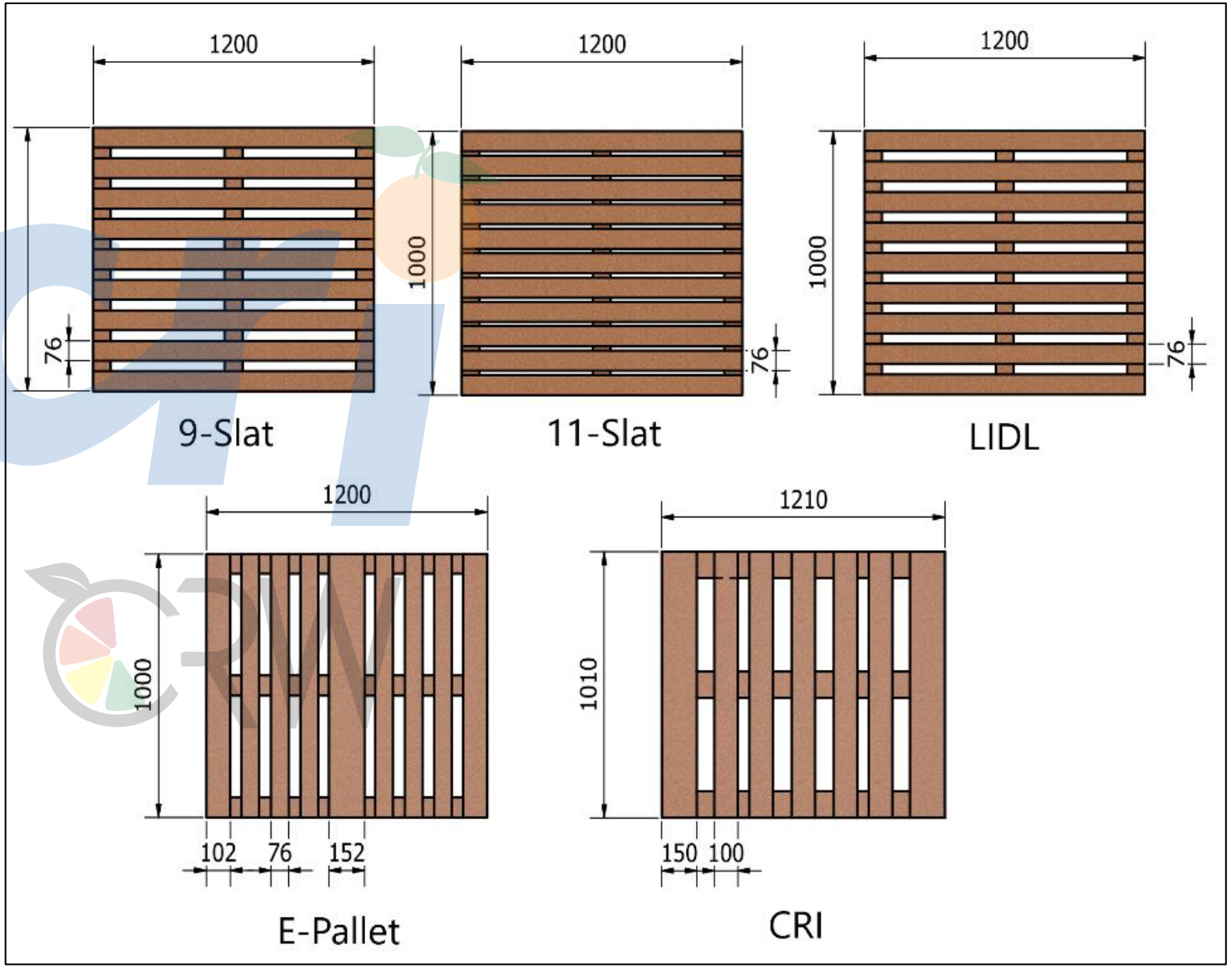
- Pallet base designs (SA citrus) are currently sub-optimal
  - Cost
  - Strength
  - Operational (manufacturing, usage)
  - Getting worse
- We do not want pallet base diversification!
  - Manufacturing is a high-throughput, low-cost game.
  - More pallet base designs = lower quality or higher costs
- Industry trends
  - We need to eliminate designs
  - Clear the board



Finalizing 5 years of research = Optibase

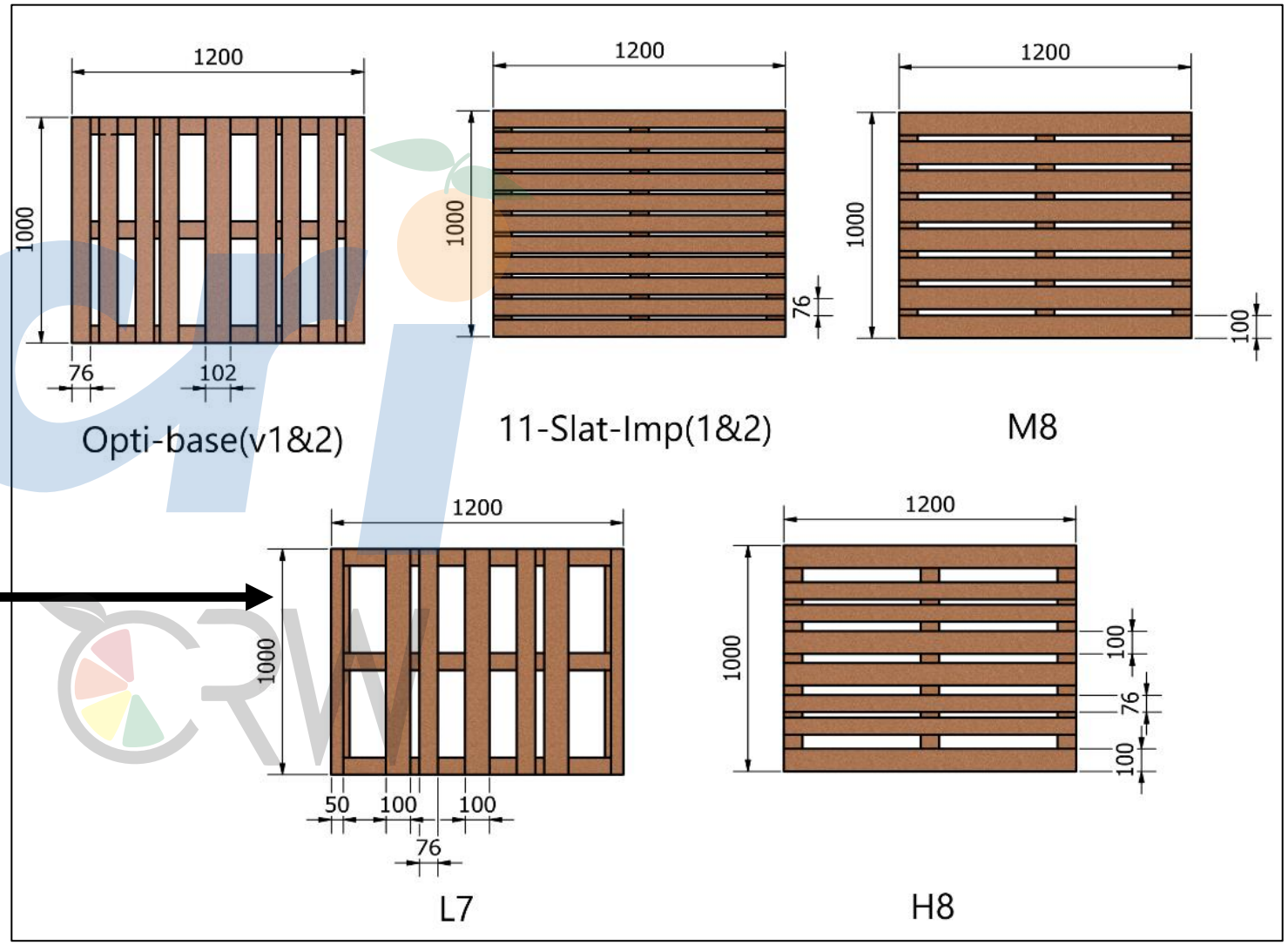
Pallet bases

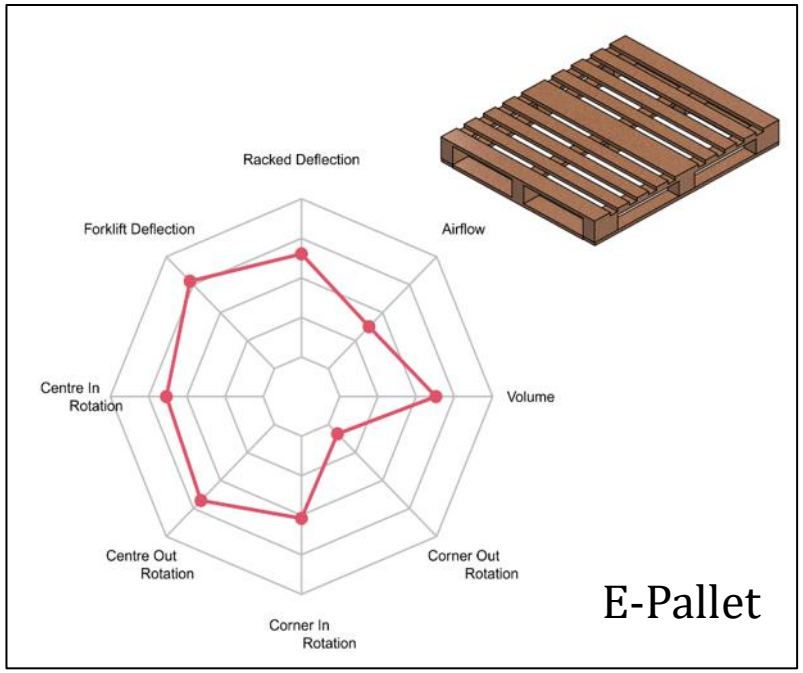
- Pallet base solution?
  - Improved design
  - Quality control
- Four-year project is complete
  - Most designs tested
  - An optimal design has been identified



Pallet bases

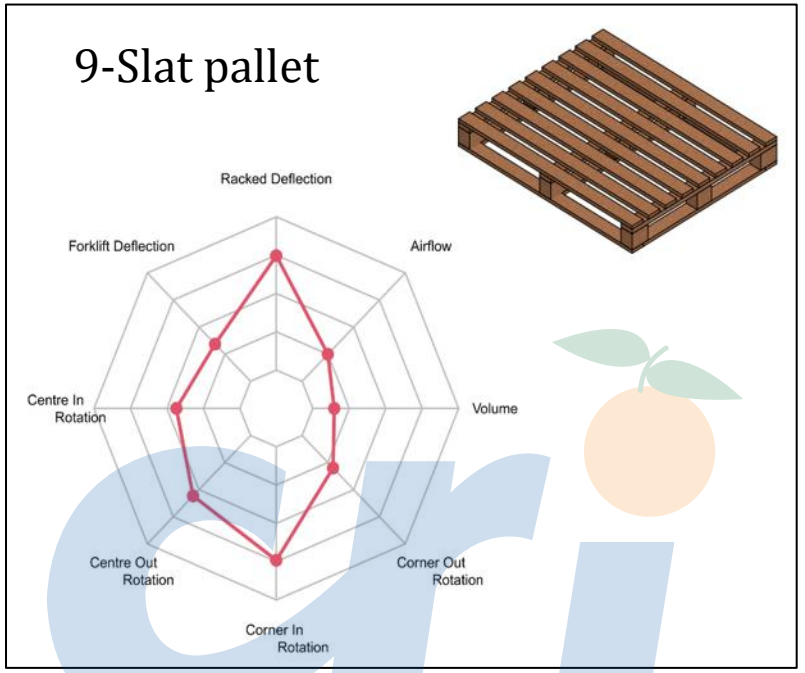
- Chile growers are leveraging off of our designs

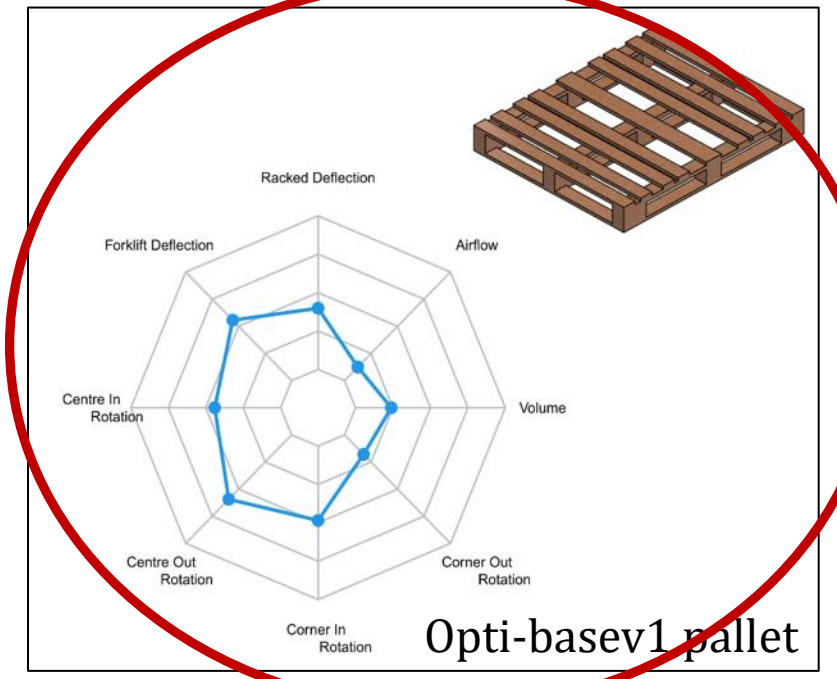




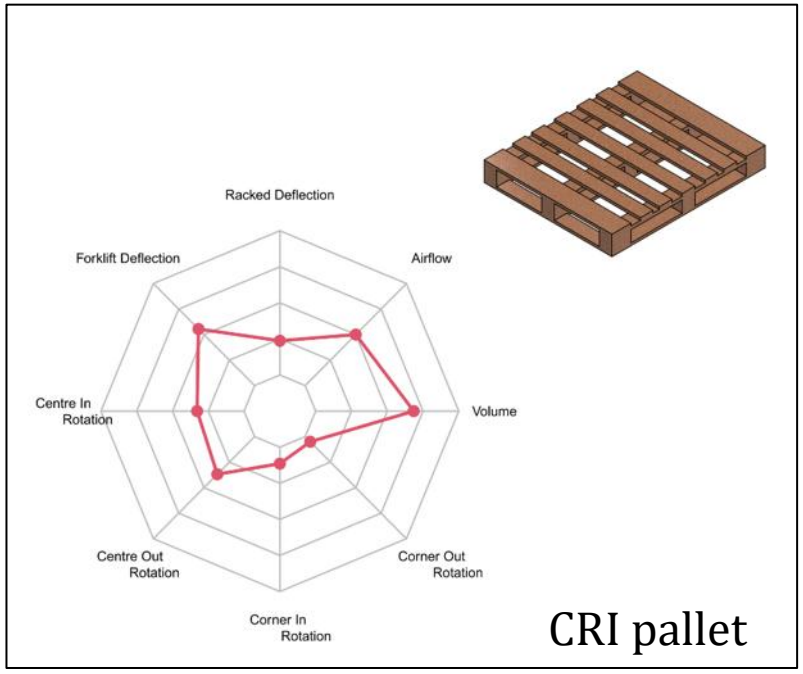
E-Pallet

9-Slat pallet



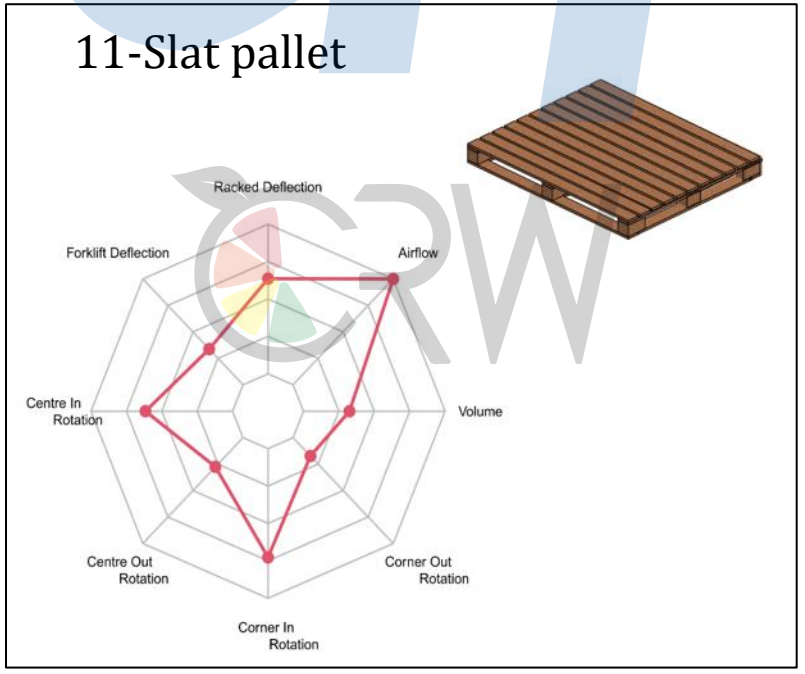


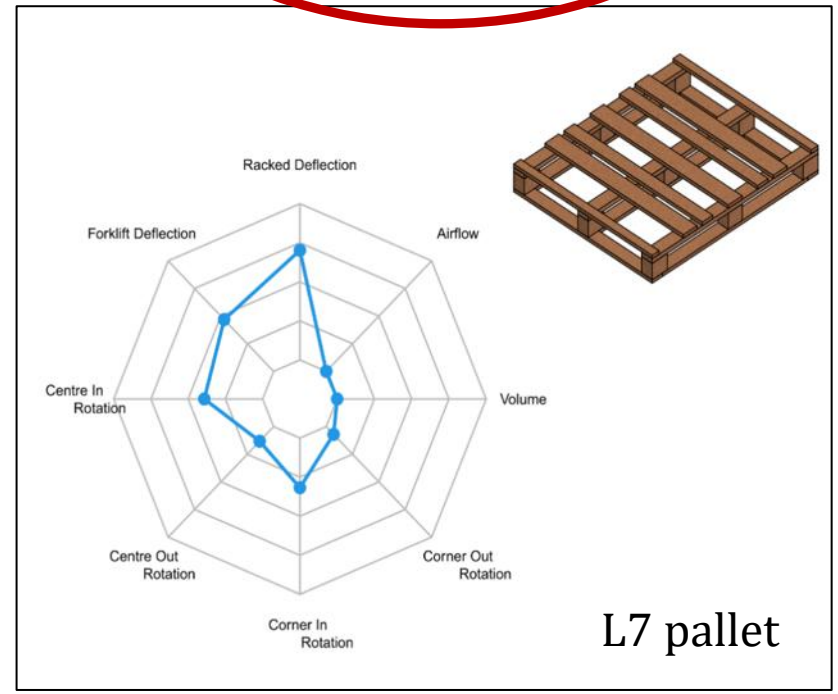
Opti-basev1 pallet



CRI pallet

11-Slat pallet

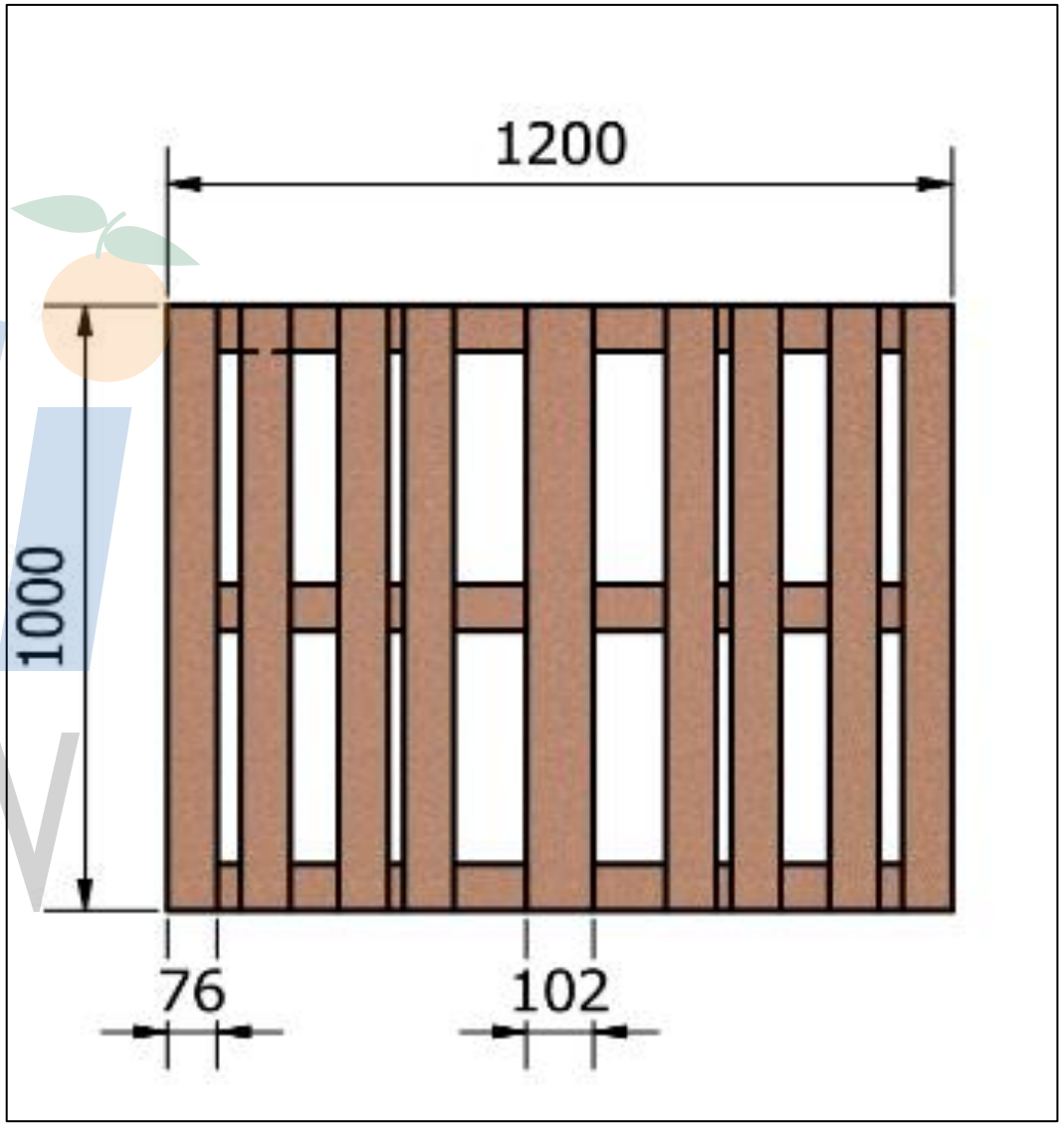




L7 pallet

Pallet bases - Optibase

- Every test is showing the Optibase is stronger, cheaper and more reliable
- John and I are working to provide
  - Guidelines
  - 21 pallet versions
- We must not let the industry spin off more designs
  - Unnecessary
  - Costly
- Design vs quality control – 40/60



Mitigating water accumulation in containers

- Water condensation arrives from the fresh air exchange vent and condenses on the evaporator coils.
- Freezing and therefore defrost cycles are present in containers with set-points below ~1°C
- Internal drain gutters are in place to drain this water away from the coils.
  - These gutters can be blocked or damaged
  - There is no way to inspect them.
  - The problem must be reported to the shipping line!

Drain gutter

Upper drain pan

Drain line exhaust

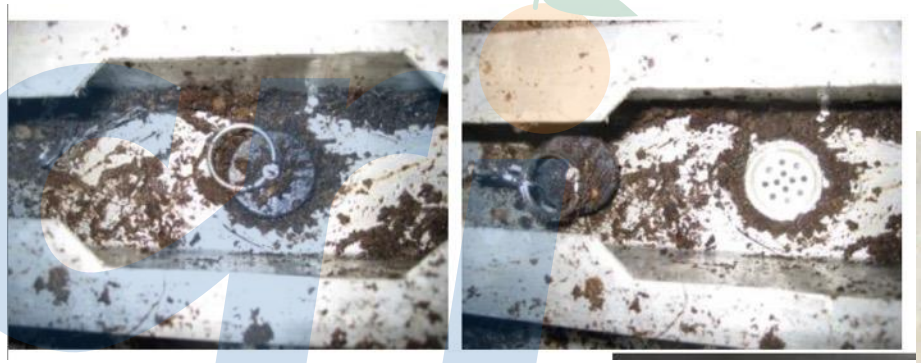
Mitigating water accumulation in containers

Draining off liquid water

- Drain line / gutters are imperfect and may be blocked (esp. iced)

Mitigating water accumulation in containers

- If the coils gutter is blocked
  - Then the four container drains need to allow the water to escape
  - Two types
    - Fixed Drain Plugs
    - Automatic Drain Plugs
  - Be default these drains are plugged
  - They are often blocked



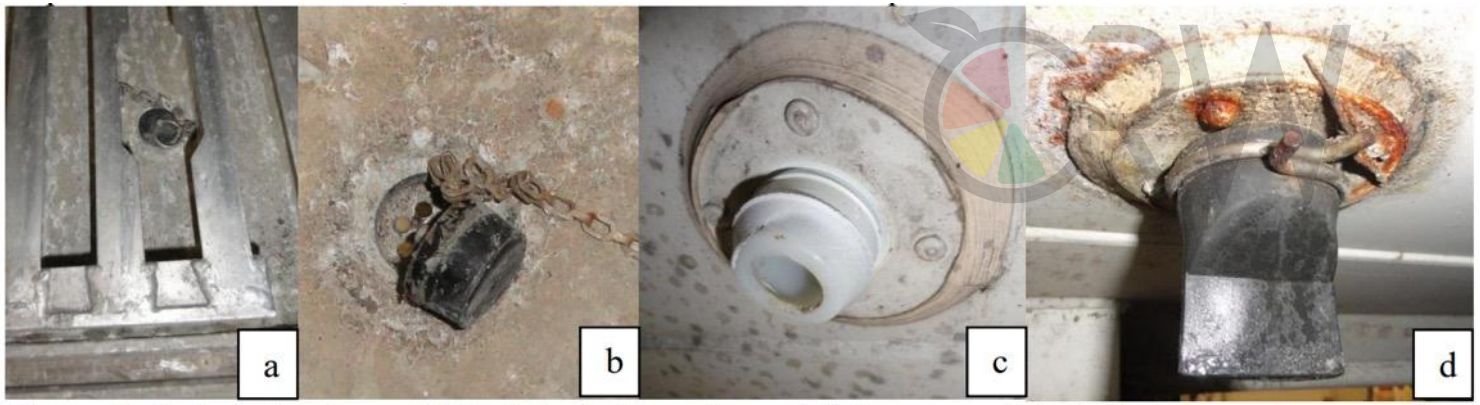
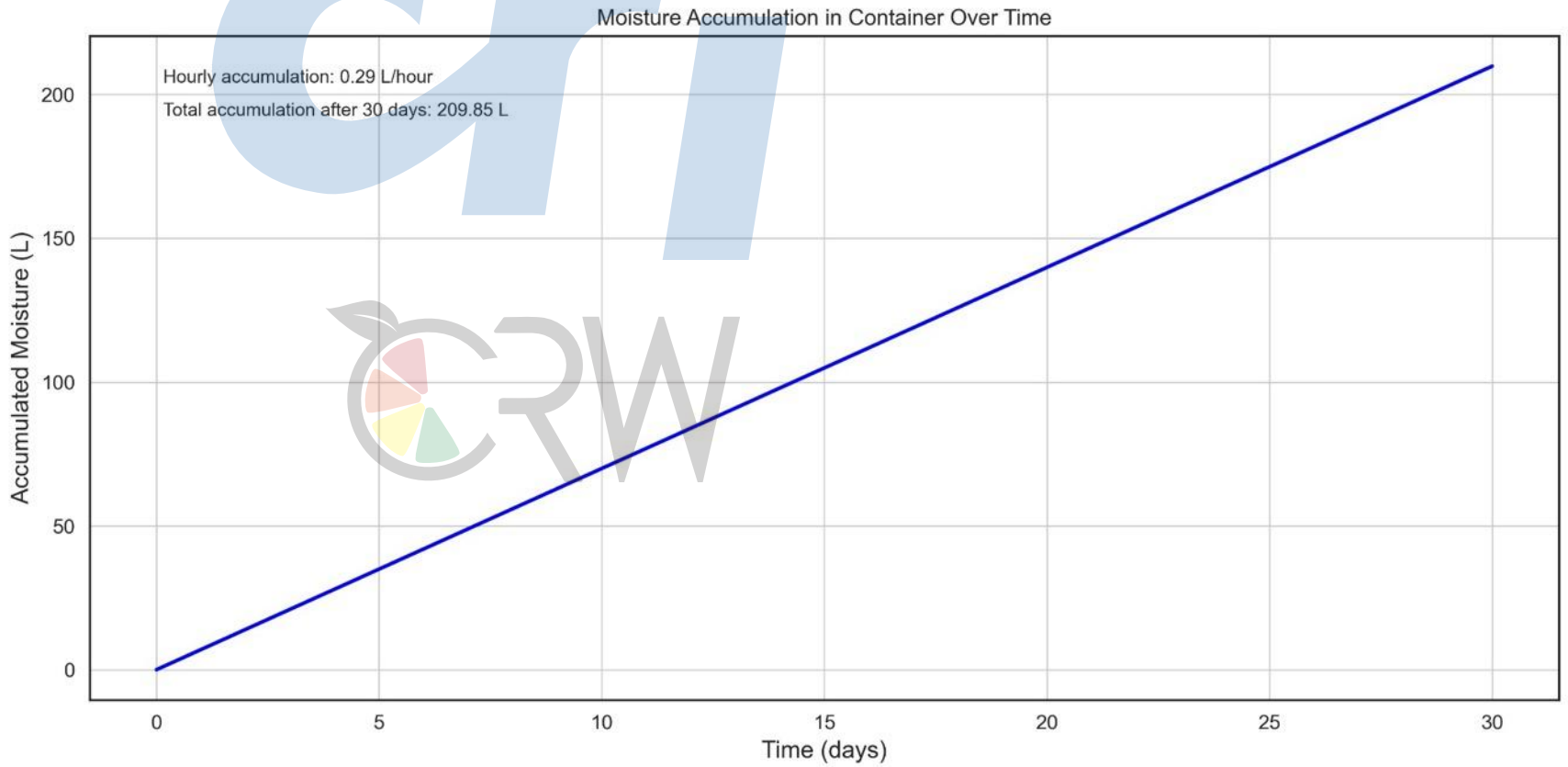


Figure 2, drain hole plugged [a], drain hole unplugged [b], output of drain holes – underneath the container without rubber sock [c], rubber sock underneath the drain hole [d].

Mitigating water accumulation in containers

- At 15 cmh (setpoint=0C):
  - 0.29 litres an hour or
  - 200 L over a 30-day period.
- Reducing the cmh still results in a problem



Container drain plugs and mitigating water accumulation

Standing solution (from 2025) – Ask Bernard for details

- Both container depots and cold stores are now authorized to remove drain plugs (previously, only depots could).
- If a PPECB inspector finds an open drain plug, they will require written confirmation from the exporter.
- Silicone sealant must not be used on container drain plugs.
- Containers belong to the shipping lines, so permanent alterations such as sealing with silicone are not allowed.

Cold stores should be instructed to remove at least one or two drain plugs

Thank you!

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