

# Using Space Based Controlled Environment Plant Growth Technology for Earth Based Production

**Dr Mark Lefsrud**



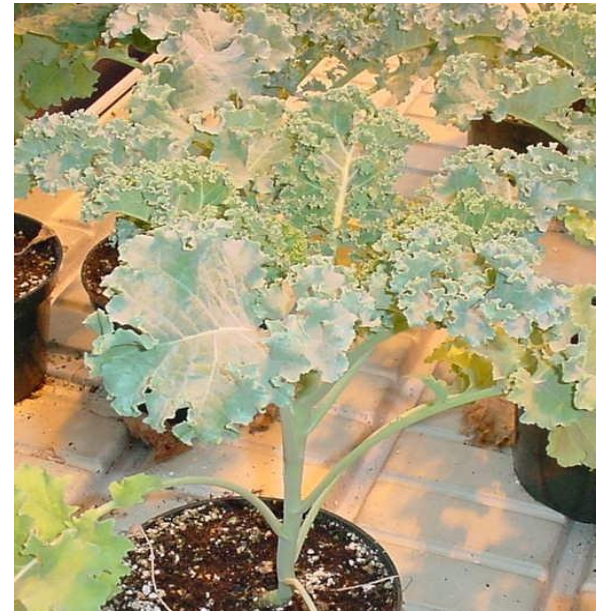
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- Hometown: Viking, Alberta.
- Education:
  - U of S (Ag and Bio Engineering) B.Sc.
  - Rutgers (Ag and Bio Engineering) M.Sc.
  - UT (Plant Sciences) Ph.D.
- Work:
  - Farm
  - NASA subcontractor
  - Oil service company
  - ORNL



# Presentation Content

- Challenges
- Factor Overview
- End Uses
- Light
- Water
- Substrate
- Atmosphere
- Sensors



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# World Challenges

## Reduce use of fossil fuels

- Energy use is high!
    - ~40% of greenhouse costs is lighting
      - LED are higher efficiency
    - ~40% of greenhouse energy is heating
      - ~20% of heat is lost through a chimney
  - Need more food
    - Most food in North America comes from California!
-

# Biomass Production System (BPS) Plant Research Unit



NASA

# NASA - Veggie



NASA

# Factors – NCR-101

- Energy
  - Photosynthetic active radiation (PAR)
  - Photoperiod
- Water
  - Temperature
  - Resupply, volume
  - pH
  - Electrical conductivity (EC)
- Atmospheric
  - Temperature
  - Relative humidity
  - Water vapour pressure deficit (VPD)
  - Concentration
    - Carbon Dioxide
  - Air Circulation
    - Air flow
    - Air changes
- Earth
  - Temperature
  - Substrate
  - Nutrition
    - Solid media
    - Liquid culture
- Space
  - Room, chamber, vessel or subspace (shelf) properties
    - Specifications
    - Barrier beneath lamps
    - Air Flow
- Plant
  - Biosensor?



# The Urban Barns Cubic Farm™ Grows, and Grows and Grows



# Greenhouse

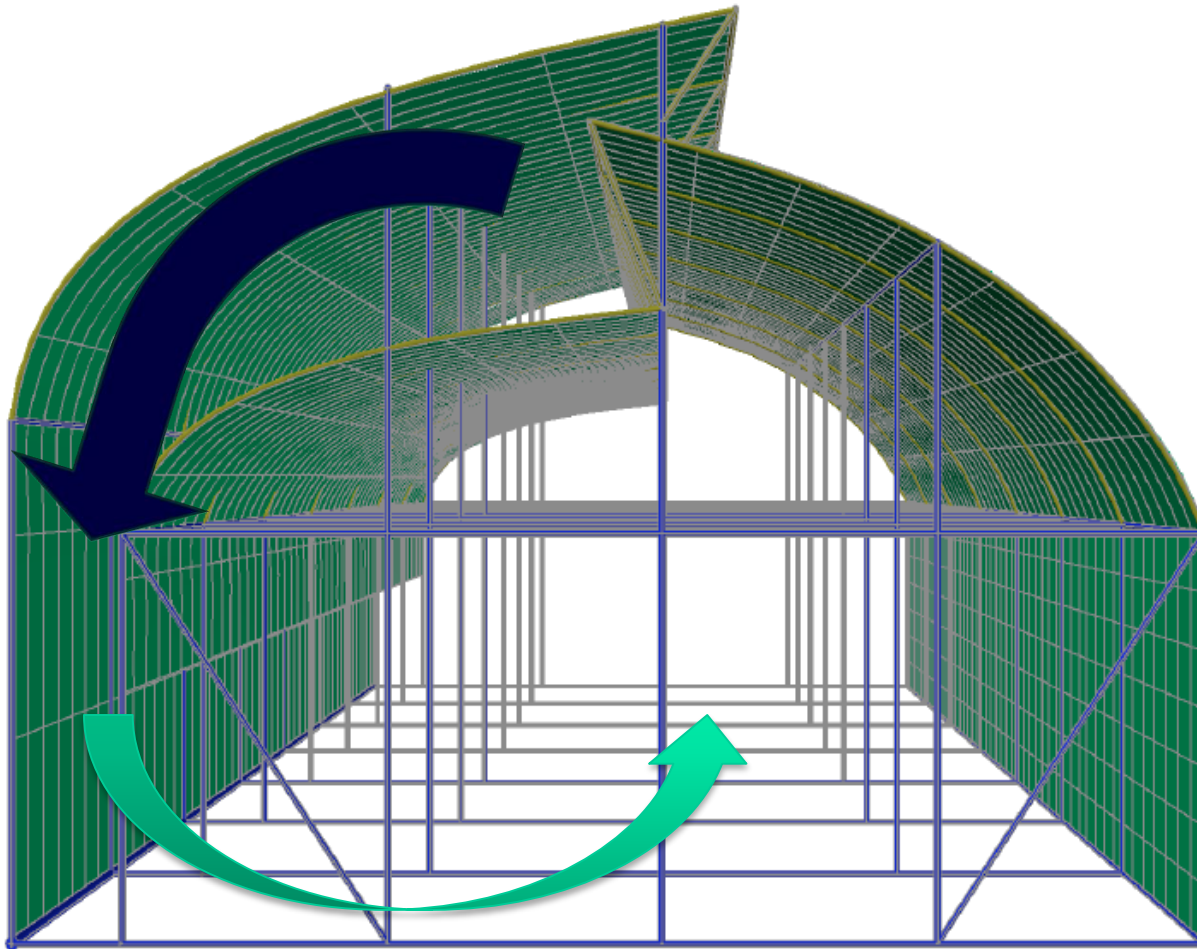


# Food SINC (Food Security in Northern Canada)

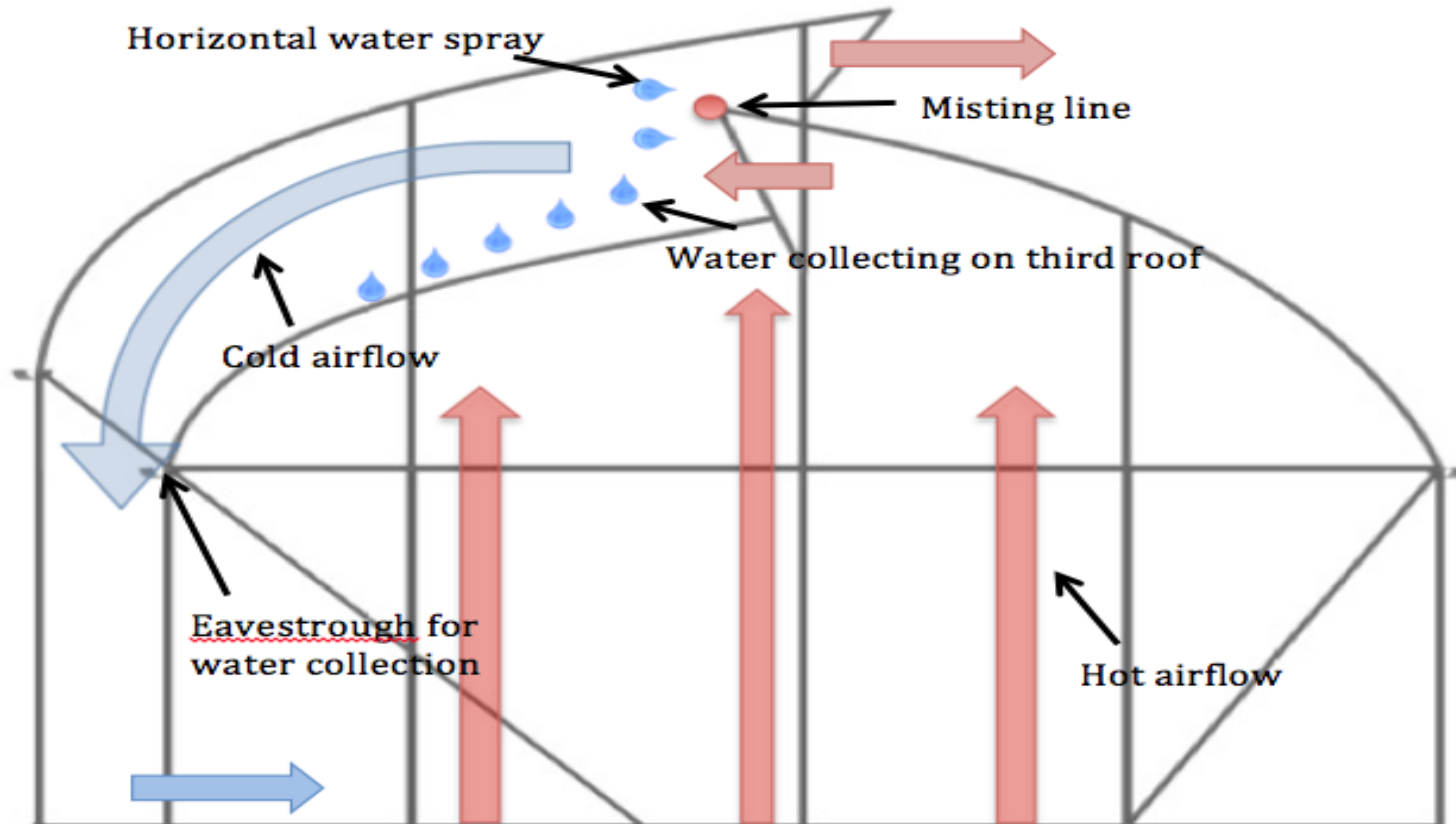


Lefsrud

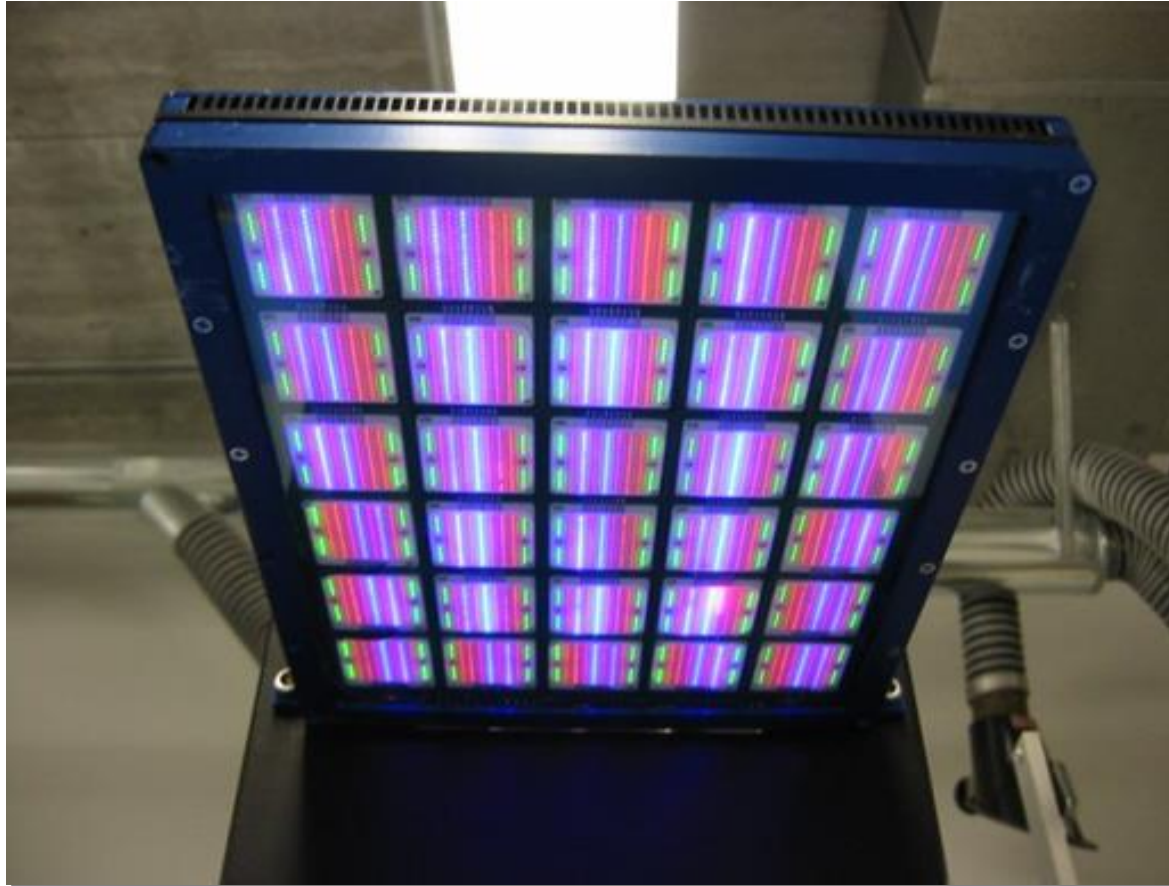
# Natural Ventilation Augment Cooling (NVAC) Greenhouse



# NVAC Greenhouse



# Light



# Light Emitting Diode

- Morphological control of plants based on wavelengths.
- Increased biomass production.



Tomato Light Testing



Cannabis  
Light  
Testing

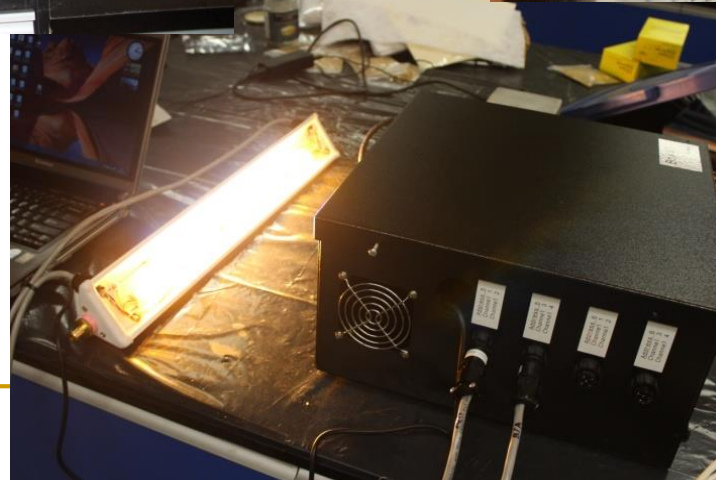


Tomato Light  
Testing (high blue)



Tomato Light  
Testing (high red)

# High Intensity LED Testing





# High Intensity LED Testing



Red LED

Reddy

# High Intensity LED Testing



Blue LED

Reddy

# Lighting



# Controlled Watering

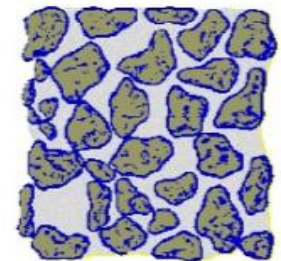
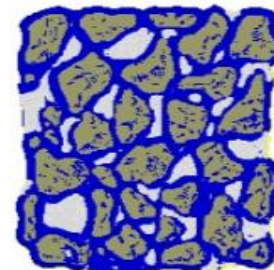
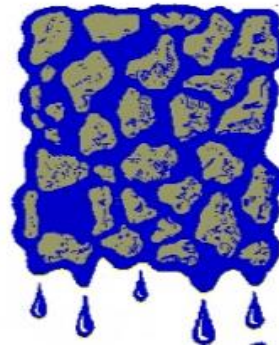


# Porous Concrete for Plant



# Advantages of Porous Concrete

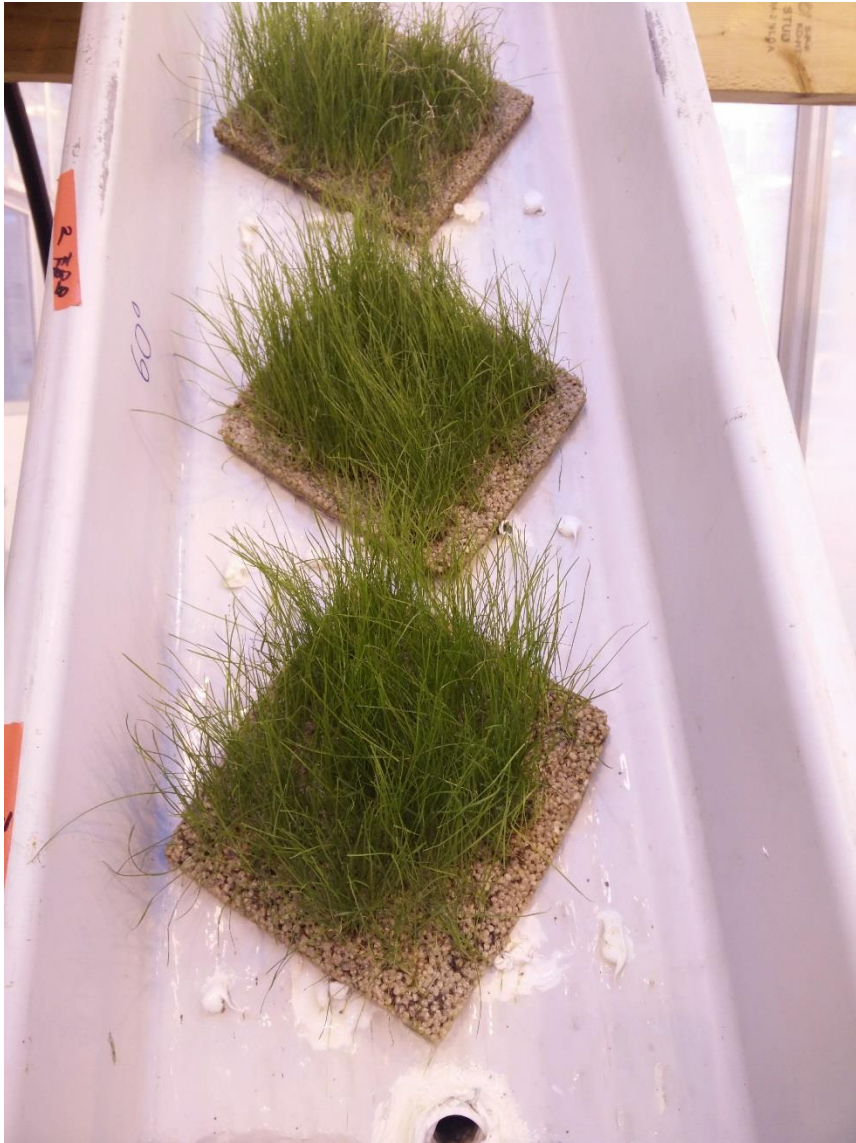
- Binding agent
- Modular
- Water holding
- Pore size:
  - Aggregate size
- Cost
- Reusable material



# Porous Concrete – Turfgrass



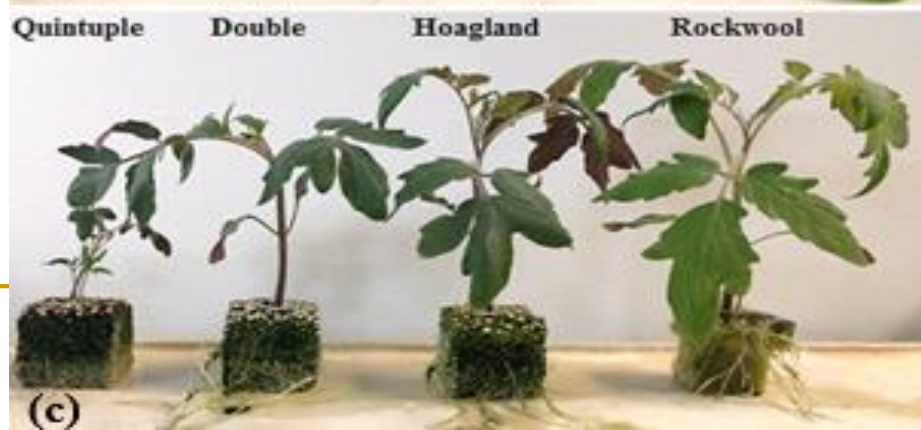
# Porous Concrete – Turfgrass



Hitti



# Porous Concrete - Nutrient



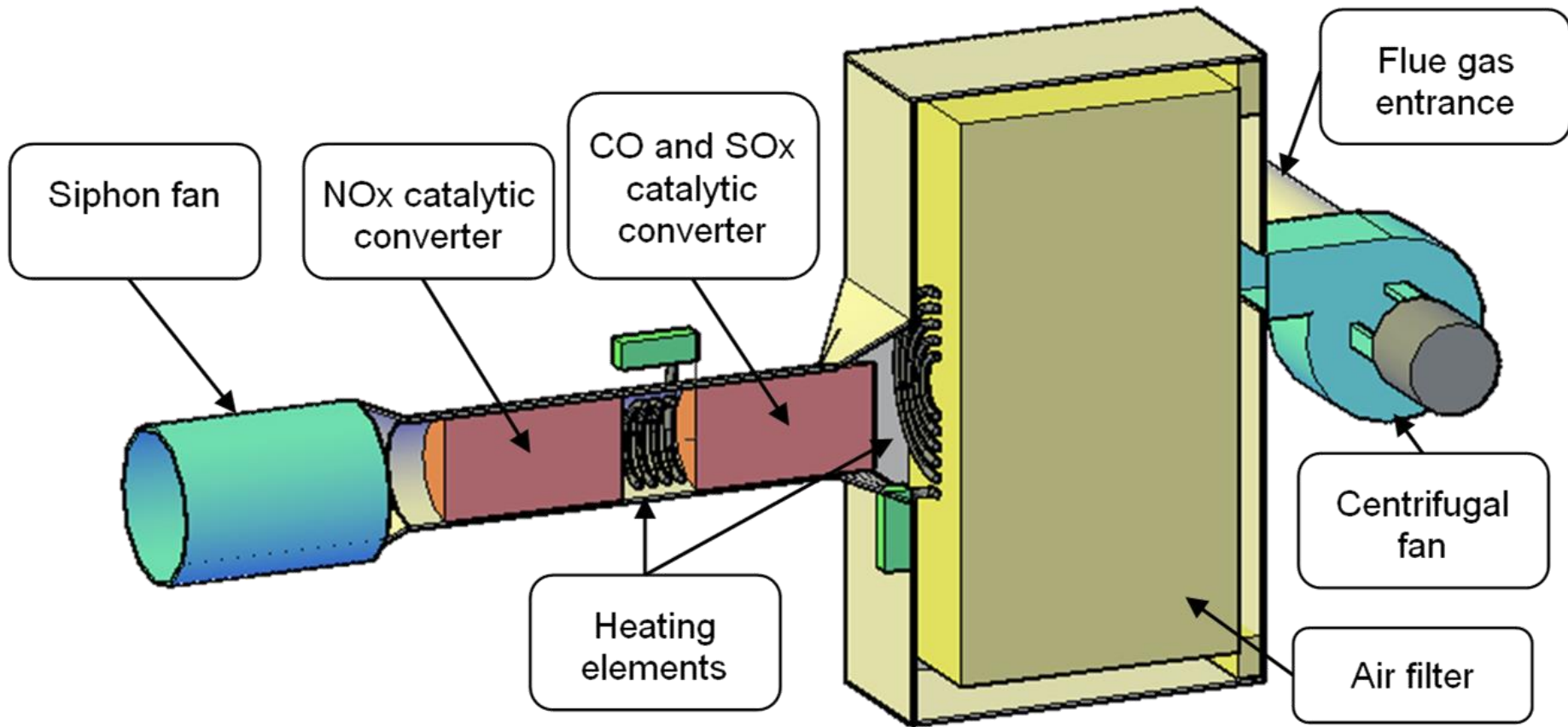
# Atmosphere – Carbon Dioxide



# Biomass Combustion for Greenhouse Carbon Dioxide Enrichment

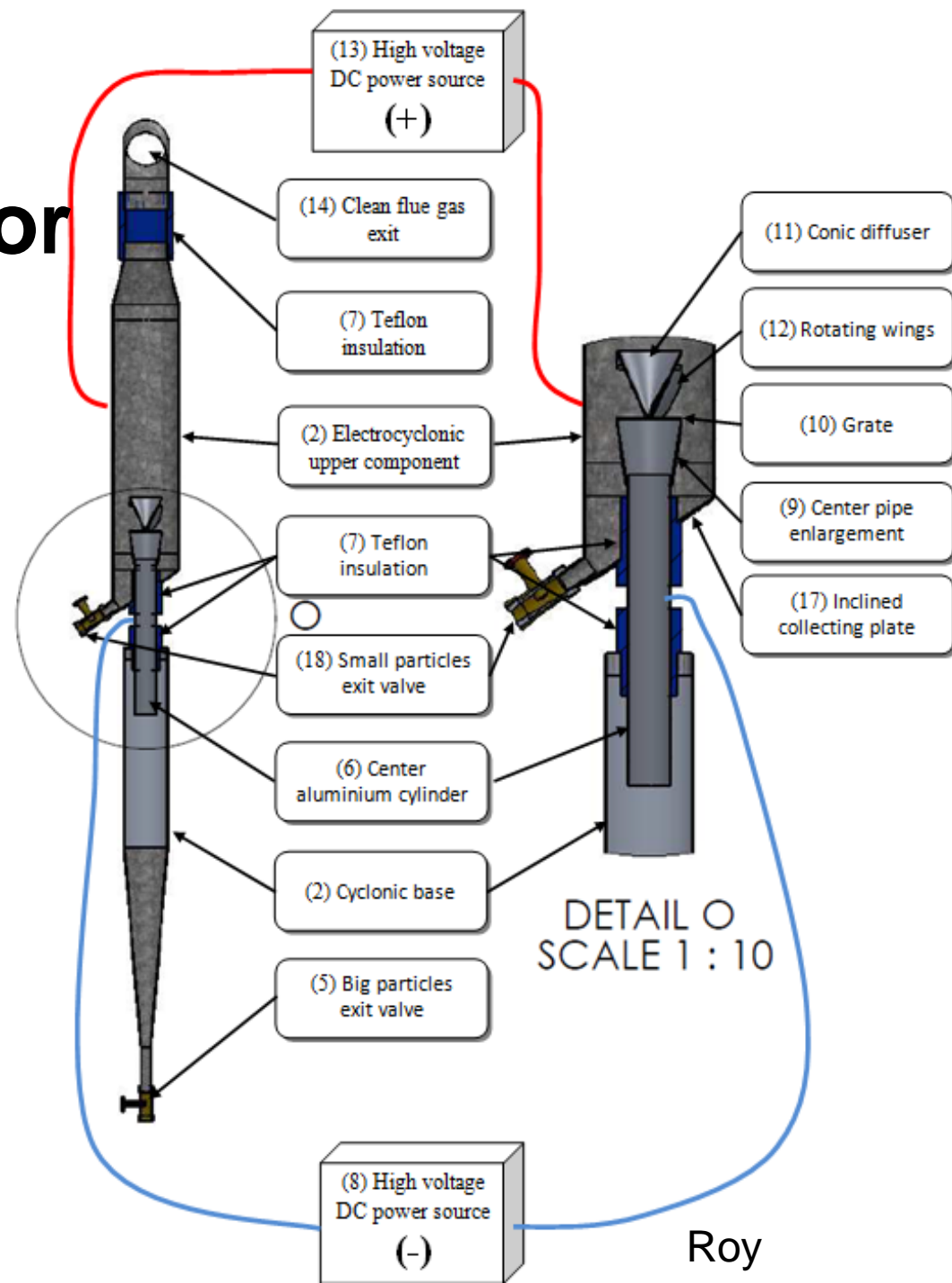


# FT1 - Detail design

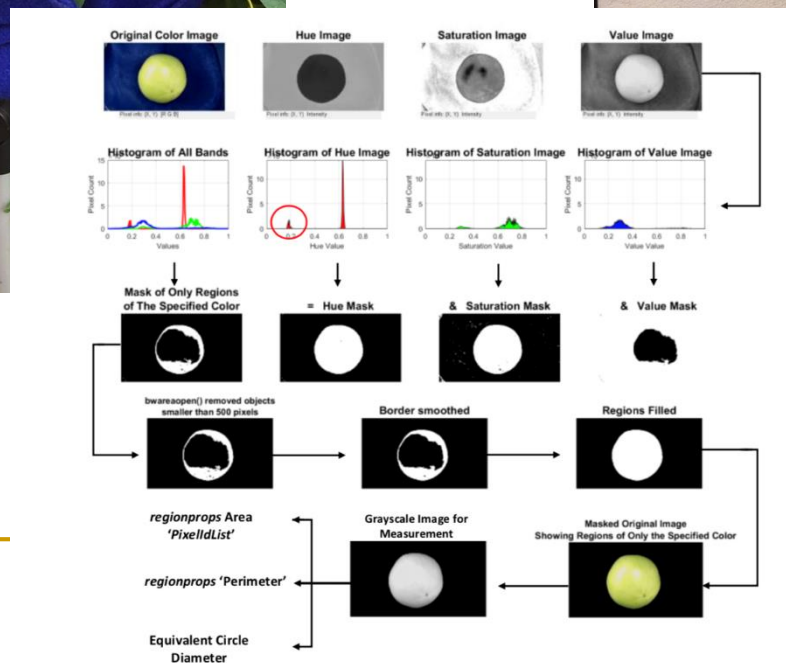


# Electrocyclonic Particles Collector (EPC)

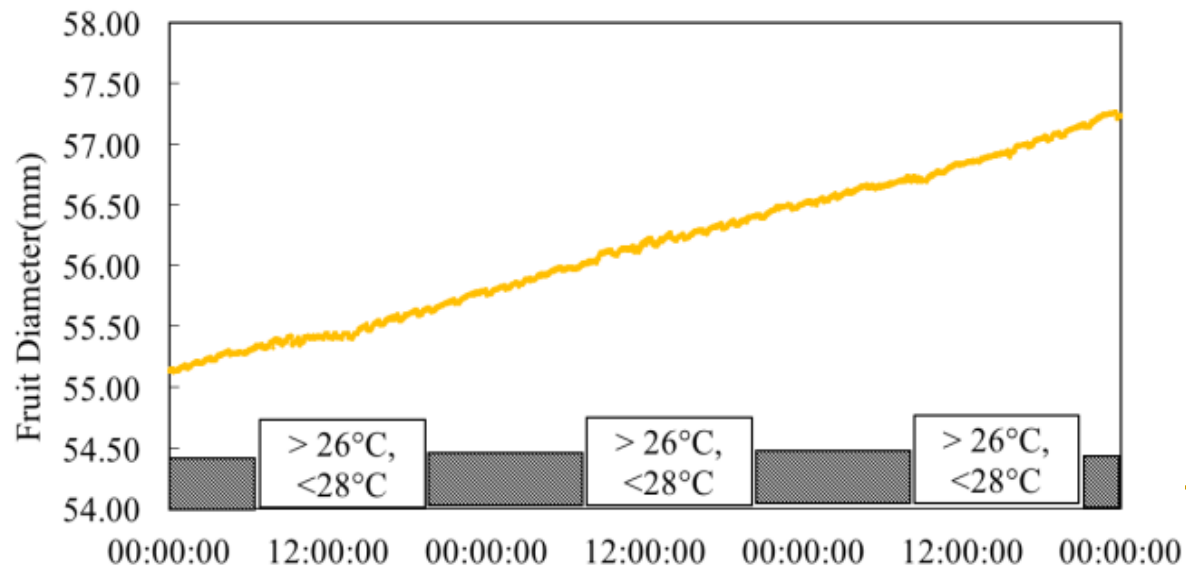
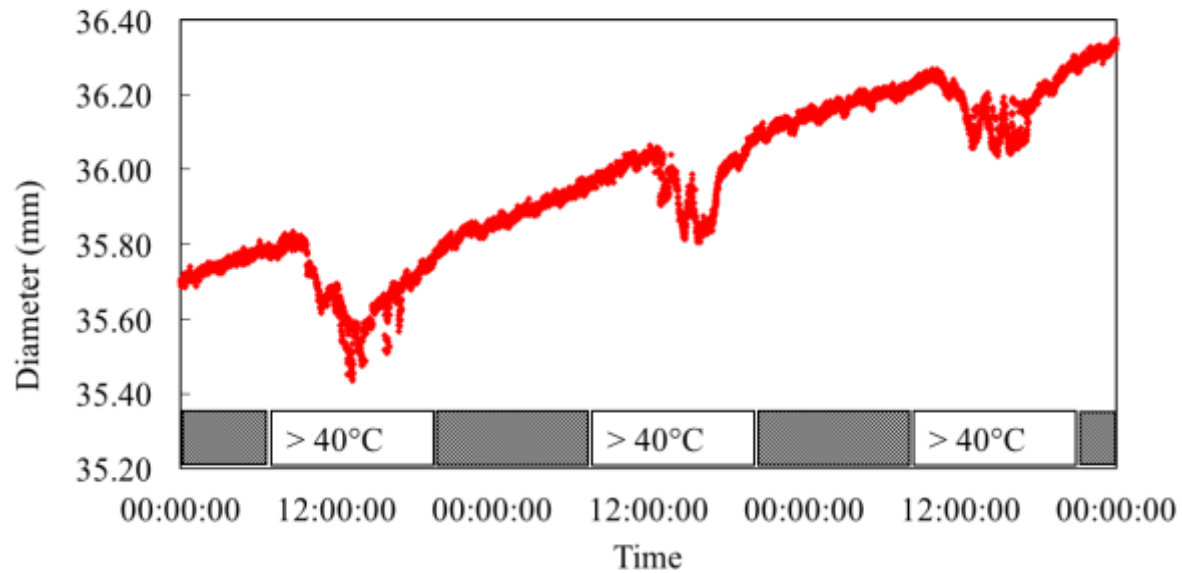
- The bottom electrocyclonic section collects particles  $> 5 \mu\text{m}$  and approximately 30 % of particles between 2.5 and  $5 \mu\text{m}$ .
- The top electrocyclonic section collects particles between  $5 \mu\text{m}$  and  $1 \mu\text{m}$ .
- The overall efficiency is greater than 95 % mass basis.



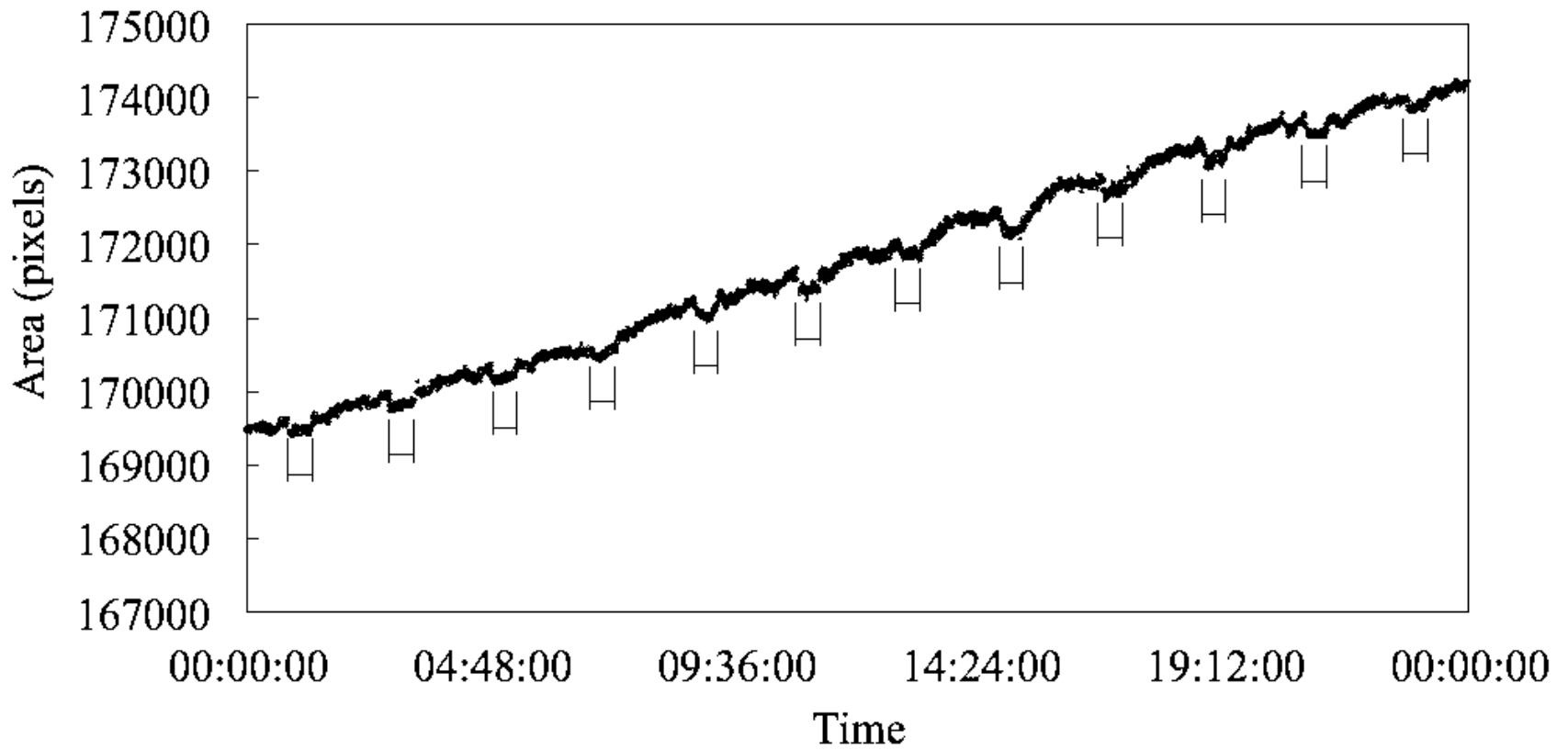
# Machine Vision



# Tomato Fruit Growth

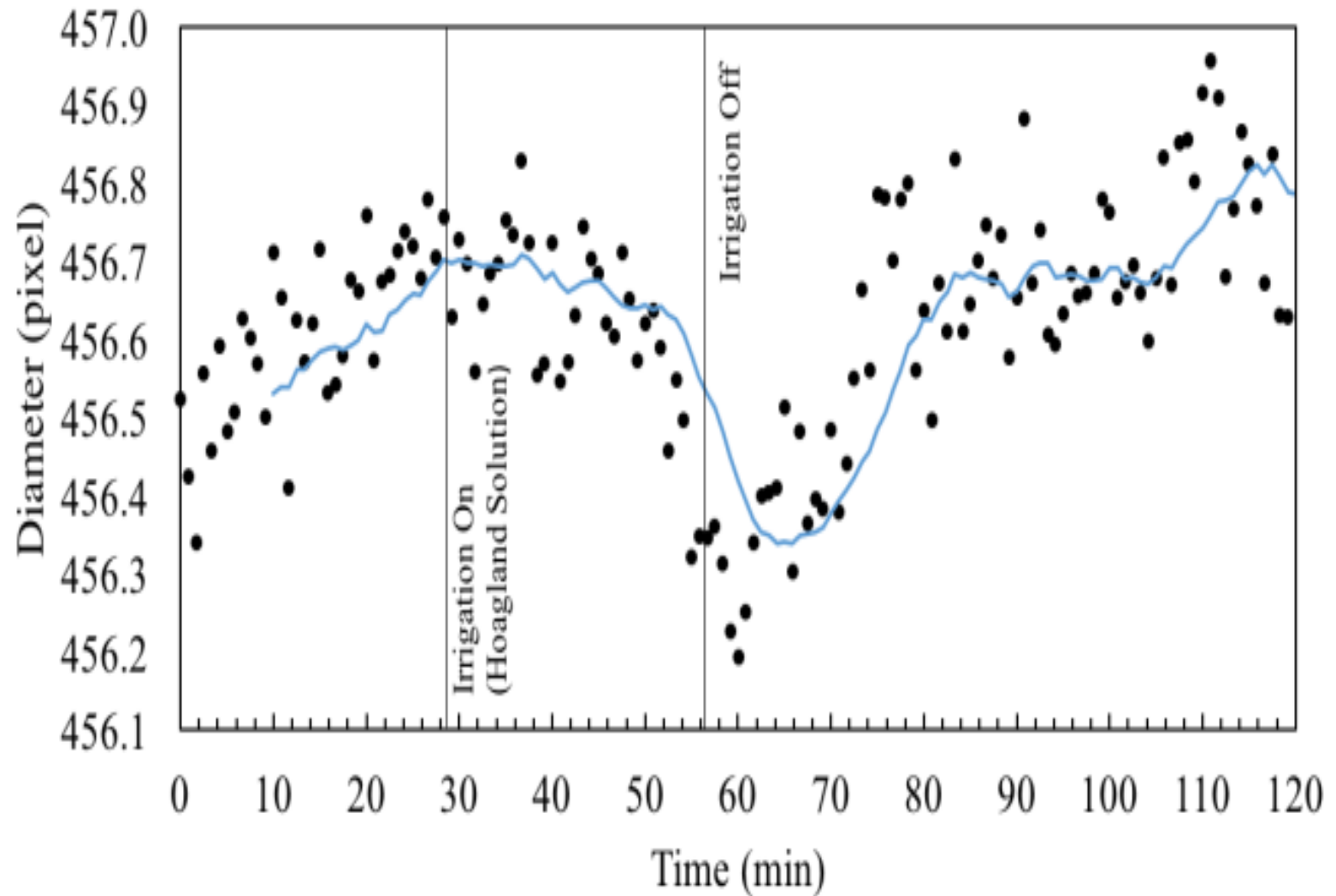


# Fruit Growth





# Fruit Growth



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