Soilless Farming: Hydroculture Systems

Implementing Integrated Soilless Agriculture

What is soilless agriculture? Hydroponics, or soilless cultivation, is a technique for growing plants using nutrient-rich water instead of traditional soil. The following are three pillars essential for successful hydroponic cultivation.

Greenhouse Design

- Multi-span structures with glass /plastic film covering
- Multi-span structures with insect proof mesh
- Modular structure house

Consideration for Viability

- Cultivation method suitability
- Local Climate familiarity
- Leafy vegetables growing needs

Crop Selection

- Identifying consumer interest or in-demand vegetable
- Considering price points and profitability
- Select seed supplier and cultivar

Greenhouse Design

A modern greenhouse operates as an integrated system, often referred to as Controlled Environment Agriculture (CEA), Controlled Environment Plant Production System (CEPPS), or Integrated Urban Controlled Environment Agriculture. These systems are designed for optimal plant cultivation, with seamless integration driving productivity in high-tech controlled environments. Ecosystems are vital in modern farming, boosting productivity, managing pests, and improving crop quality. Their careful selection impacts both farm economics and environmental sustainability. The following are the major components of an effective CEA system:

Greenhouse Structure GS

Structure components:

- Flexible and scalable solutions for controlled environment
- Climate control fans
- Automated solar screen with integrated supplemental lighting systems

Growing System GS

Basic concept:

- Plant roots are suspended directly in nutrient-rich water
- Net pots, polyurethane (PU) foam or containers to hold plants
- Closed loop system (continuous process of cycling resources the same water and nutrients)

Nutrient Delivery System NDS

System components:

- Sump tank, water source and self-filling water top-up system
- Smart nutrient monitoring (e.g. EC and pH) for adjustments
- Irrigation line, valves, filters and pressure regulators
- Soluble fertilizers

CEA Infrastructure and Systems

- Supporting foundation, shape, and framing materials
- Climate control sensors
- Irrigation system for delivering nutrients and farming equipment
- Rooftop transparent materials
- Perforated side screen
- Solar screen (Shading curtain)

Poly Greenhouse

Framing

Solar Screen/ Ventilation fans

Crop nutrient monitoring (EC/Temp/ pH sensors)

Production system - Deep Water culture (DWC)

Perforated side netting as pest barrier

Lux-responsive shading system

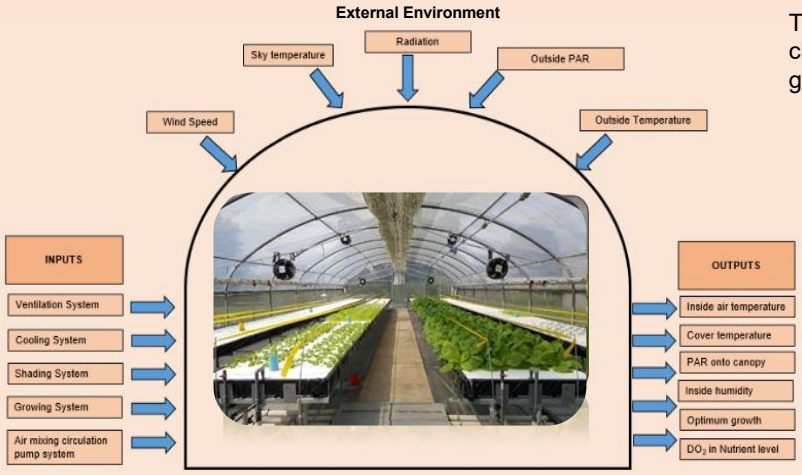
Smart fertiliser dispensing and self-filing water top up system

Soilless Farming: Hydroculture Systems

Climate Adaptation for Soilless Farming

Climate change impacts, particularly rising temperatures, challenge soilless cultivation of Asian greens in Singapore. Active greenhouse climate control is crucial to mitigate **Heat Stress**, which can significantly impair leafy vegetable growth, yield, and quality.

Greenhouse climate factors, difference between greenhouse and external climate



The values of these parameters, their interconnection and changes determine the condition and regulating of the greenhouse climate *(GHC Bullentin,1997)*.

External Environment

Greenhouse heat management is crucial for maintaining optimal growing conditions:

- Trapped radiation and outdoor conditions causes greenhouse heat accumulation.
- Shading can reduce radiation and mitigate heat build-up.

Inputs

To reduce the heat accumulation, several interventions could be considered including:

- Ventilation systems
- Shading systems
- Water aeration
- Cooling systems

Outputs

Understanding greenhouse heat dynamics enables better climate control and crop management through:

- Optimising temperature control and relative humidity
- Optimising light exposure during peak hours
- Ensuring sufficient oxygen in water for healthy plants
- Creating an ideal micro-climate around plant canopies

Major Symptoms Caused by Heat Stress

Improper climate conditions in the greenhouse can significantly impair plant growth and development, leading to compromised plant health and substantially reduced crop yields. For example, extended periods of high ambient temperatures (35-40°C) increase water temperature and impact root growth. Warmer water (29-32°C) decreases oxygen availability (to 2-3 mg/L), leading to poor root growth. An oxygen level of 6 to 8 mg/L is often considered optimal for most plants. Heat-sensitive Asian greens include Choy Sum, Bok Choy, Amaranthus, Gai-Lan, and various lettuces varieties.

Sturdy leaves structure

Heat

Plant wilting and limp leaves

Heat

Underdeveloped plants with drooping leaves

Robust and healthy roots development

Overall root system development is impaired

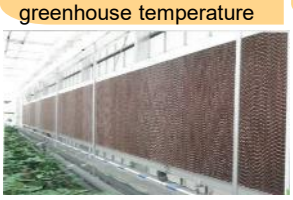
Changes in branching patterns and root distribution

Strategies for Alleviating Heat Stress

Recommendations to mitigate heat stress:

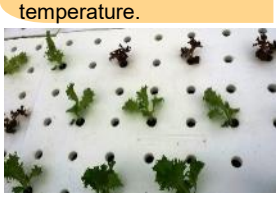
1. Optimise cooling systems
2. Improve air circulation
3. Determining ideal plant-to-plant distance
4. Use reflective black shading material for shading

Evaporative Cooling Pad.
Wet wall or pad-and-fan systems to reduce greenhouse temperature



Shading & Ventilation.
30-50% shading and 0.5 to 1 m/s air velocity recommended for most Asian greens

Optimal Spacing.
15-20 cm spacing between plants to reduce microclimate temperature.



Soilless Farming: Hydroculture Systems

Select Variety for Market Demand

Why Asian Green?

Adaptability
- ✓ Fast-growing to various growing condition
- ✓ Suitable for urban farming

Cultural preferences
- ✓ Asian cuisine rely on these vegetables
- ✓ Favoured consumed vegetables locally

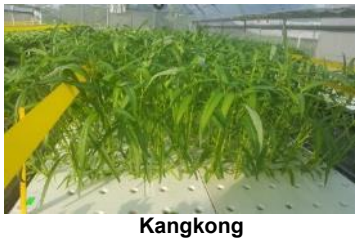
Economic factors
- ✓ Local production can be more cost-effective than importing
- ✓ Supports local farmers and agricultural businesses

Climate suitability
- ✓ Enhances self-sufficiency in vital vegetable production when crises occur
- ✓ Helps maintain a stable local food supply

Many Asian Greens have short growing cycles and thrive in greenhouse environment


Amaranthus


Gai-Lan


Kangkong


Leaf Mustard


Xiaobacai


Cai-Xin


Nai-Bai


Chinese Cabbage

Greenhouse Growing Systems Commonly Used for Asian Greens in Singapore

Soilless Culture


Mobile Gully System


Deep Water System


Overhead Fertigation System

Soil-based Culture


Soil-based Drip System


Soil-based Sprinklers System

Find out more!

The Singapore Food Agency (SFA) had recently announced the $70 mil Agri-food Cluster Transformation (ACT) Fund 2 which supports capability development, productivity improvements, and infrastructure upgrades. Farms can leverage on the Capability Upgrading component of ACT Fund 2 to adopt energy-efficient equipment and technologies from SFA's pre-qualified list. This will help farms improve energy efficiency and manage production costs to strengthen long-term resilience.

Let us know your thoughts

About the Author

Mohd Suhaime, is knowledgeable in hydroponic farming with over four decades of expertise, is a member of the Agri-Technology and Food Innovation Department. His portfolio includes contributing the "Singapore Urban Farming Project", a collaborative smart farming initiative, and implementing a Soilless Strawberry Cultivation project with Pokka Singapore. Additionally, Suhaime provides technical guidance to the local farming community.

Reference:

1. Zhao,X, 2022 Morphological and Physiological Response Mechanism of Lettuce (*Lactuca Sativa* L.) to Consecutive Heat Stress. Scientia Horticulturae. https://www.sciencedirect.com/journal/scientia-horticulturae
2. Maludin, A.J., Lum, M.S., Mohd Lassim, M. and Gobilik, J., 2020. Optimal plant density, nutrient concentration and rootzone temp https://www.researchgate.net/publication/349103171_Optimal_Plant_Density_Nutrient_Concentration_and_Rootzone_Temperature_for_Higher_Growth_and_Yield_of_Brassica_rapa_L_'Curly_Dwarf_Pak_Choy'_in_Raft_Hydroponic_System_Under_Tropical_Climate
3. Kozai, T., Kubota, C. and Kitaya, Y., 1997, February. Greenhouse technology for saving the earth in the 21st century. In *Plant Production in Closed Ecosystems: The International Symposium on Plant Production in Closed Ecosystems held in Narita, Japan, August 26–29, 1996* (pp. 139-152).
4. Kourani, M., Mohareb, F., Rezwan, F. I., Anastasiadi, M., & Hammond, J. P. (2022). Genetic and Physiological Responses to Heat Stress in Brassica napus. Frontiers in plant science, 13, 832147. https://doi.org/10.3389/fpls.2022.832147

Source of picture Pilot Test Trial on Asian Greens (AVA - Horticulture Technology Department)