Introduction to Plant Factory (Controlled Environment)

Protected Horticulture
– *Environmental Control in CE*

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Environmental Control in CE

Temperature	• Heating / Cooling
Light	• Supplemental Light
Relative Humidity	• Humidifier / De-humidifier
CO_2 fertilization	• CO2 injector
Irrigation and Fertigation	• Irrigation/fertigation Systems
ICT Control Systems	• Automation / Mechanization

Heating System

Unit Heater System

- Warm air is blown from unit heaters

Central Heating System

- Central boiler that produces steam or hot water
- Through radiating mechanism in the greenhouse

Solar heating system

- Too expensive yet

Heat Distribution

- HAF System
  - Horizontal Airflow Fan
  - Movement of air and heat
  - Air circulation

Minimum and Maximum airflow velocity
50 – 100 fpm (feet per minute)
0.25 – 0.5 m/s

Greenhouse Heating

Insulation

- Stores only 5.8-12.2% of solar heat
- Depends on structure, orientation, and covering
- Daytime – Maximum light penetration
- Night – Inhibit radiation heat loss – heat curtain

Ventilation

- Inhibit heat stress
- Controlling RH
- Influx of CO_2 and efflux of toxic gases

Heat Blankets (Thermal Screen) prevent convective and radiant heat loss

Roll-up Type Ventilation

Roof and Side Window Ventilation

HAF fans

Greenhouse Cooling

Passive Ventilator Cooling

- Roof and side ventilators

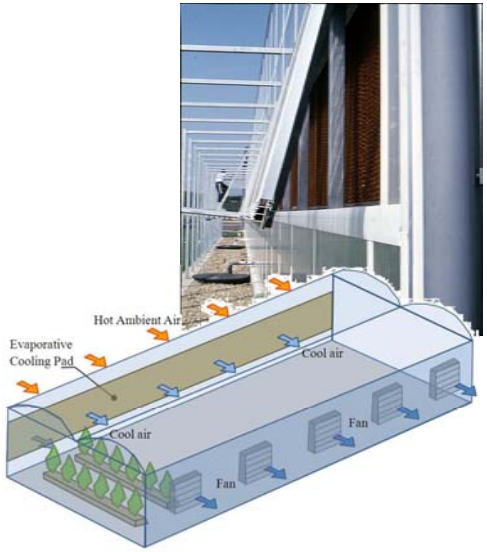
Active Cooling Systems

- Fan and pad system
- Fog system

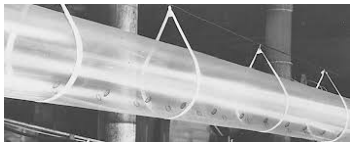
Even during the winter time

- No ventilation due to too cold temperature
- Convection-tube cooling / HAF cooling

Fan and Pad System



Convection Tube



Light Environment

Light Intensity	• Reduced due to.. • Structure / Glazings
Light Distribution	• Light diffusion
Light Quality	• Reduced UV light • Need PAR
Light Duration	• Artificial photoperiod control • Night Break or Black Cloth

Supplemental Lights

Table 7.5 Light Emission Principles and Corresponding Major Electric Lamps and Devices

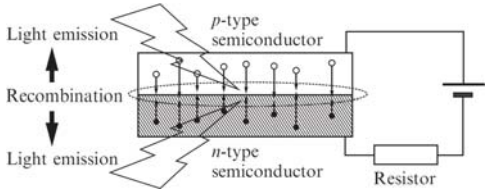
Light Emission Principle	Electrical Lamps/Devices
Incandescence	Incandescent lamps
	Halogen incandescent lamps
Discharge light emission	Low pressure discharge lamps
	Low pressure sodium lamps
	Fluorescent lamps
	Preheat fluorescent lamps
	Rapid-start fluorescent lamps
	High-frequency fluorescent lamps
	Cold cathode fluorescent lamps
	High pressure discharge lamps
	High pressure mercury lamps
	Metal halide lamps
	High pressure sodium lamps
	High pressure xenon lamps
Electroluminescence	Intrinsic electroluminescence devices
	Inorganic electroluminescence devices
	Injection electroluminescence devices
	Light-emit diodes
	Organic electroluminescence devices

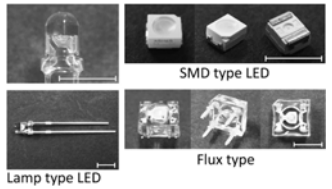
Supplemental Lights (補光)

Lamp	Eff	L Qual.	Duration	Power	Uses
Incandescent	7%	r, fr	6 m	Low	Photoperiod
Fluorescent					
Cool white	21%	b, g, y	2 y	Low	Germination/GC
Warm white	21%	b, g, y	2 y	Low	Germination/GC
High Intensity Discharge (HID)					
High pressure mercury	13%	b, g, y, o	3 y	High	Greenhouse
Metal halide	20%	b, g, y, o	2-3 y	Huge	Multi-use
Low pressure sodium	27%	g, y, r	4-5 y	Med	Supplemental
High pressure sodium	25%	y, o, r	3-4 y	High	Supplemental

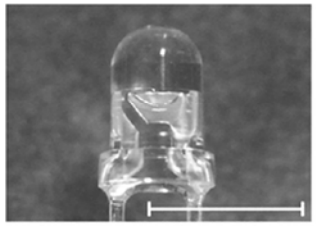
Light Emitting Diode (LED)

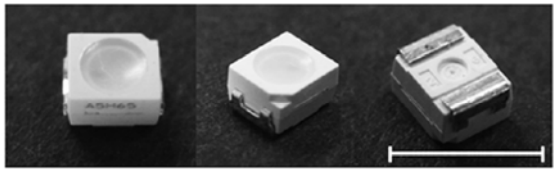
- Robust, stable output
- Long lifespan
- Light weight
- Specific wavelength
- Expensive yet



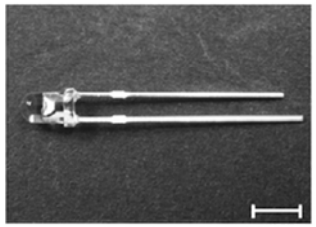


LED Types

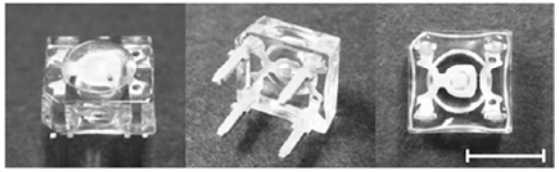




SMD type LED



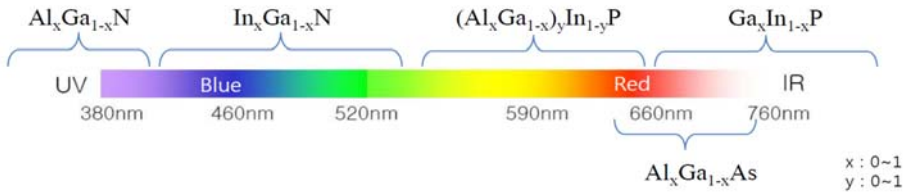
Lamp type LED

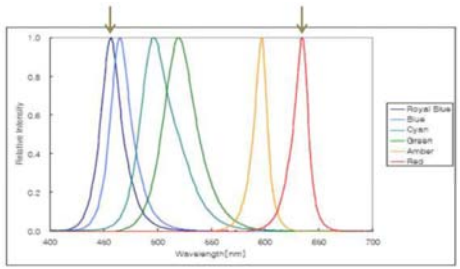


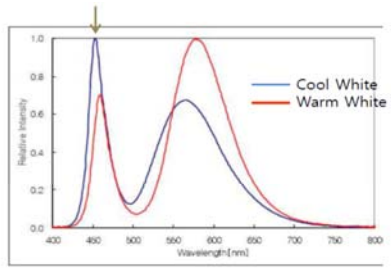
Flux type

Various Peak Wavelengths

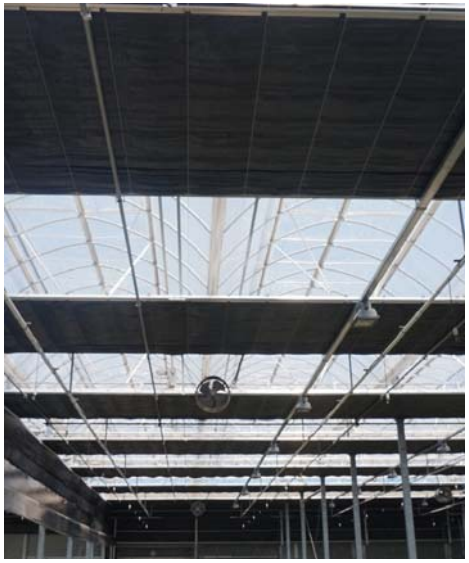
- Various chemicals to make different wavelength







Shading / Black Cloth

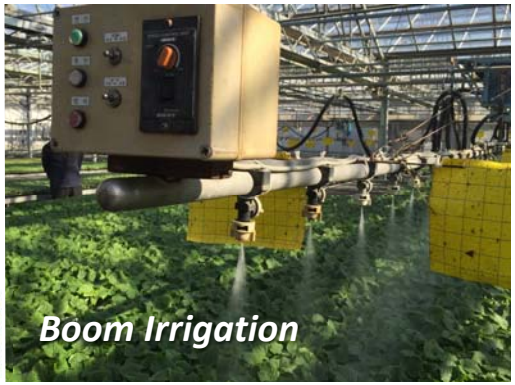


Controlling RH / VPD

Humidifier	• Fog / Mist System • Transpiration of the plants
Dehumidifier	• Greenhouse Size
Requires Good Aeration	• Air circulation fan

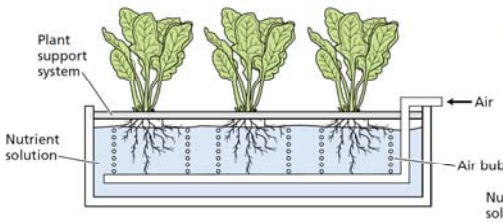
Irrigation Methods

Top Watering (Overhead)	• Hand watering • Sprinkler / Boom
Drip Irrigation	• Drip tube or emitter stake • Efficient
Subirrigation	• Using capillary action • Ebb and Flow / Through
Hydroponics	• Soilless culture • NFT / DFT / Aeroponics

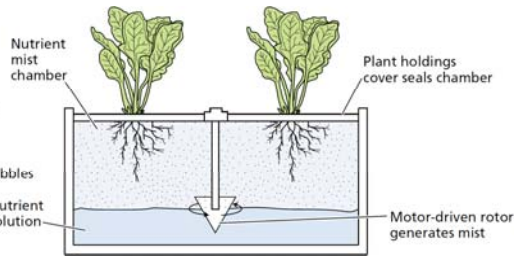


Hydroponics

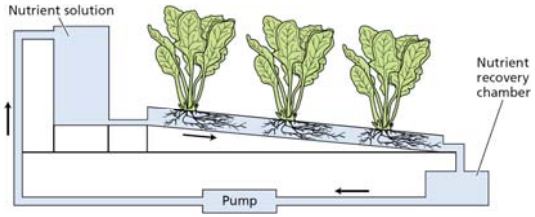
Deep Flow Technique



Aeroponic System



Nutrient Film Technique



More Details in Hydroponics Chapter

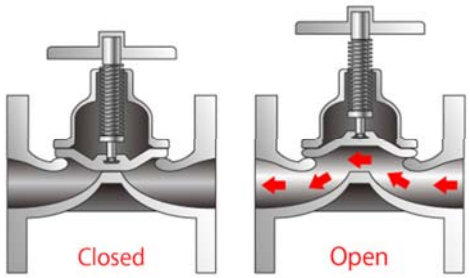
Irrigation Materials

- **Pipe**
  - Various pipe materials
  - Mostly PE (Polyethylene) pipes
  - Soft tubes for drip irrigation

- **Pump**
  - Pressure compensated > 1.5 kg·cm^2
- **Filter**
  - Disc and Screen Filters

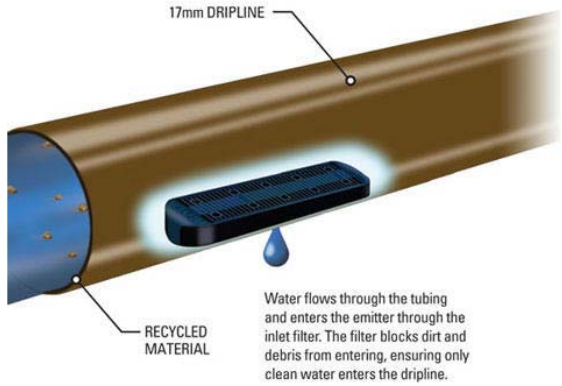
Irrigation Materials

- **Valves**
  - Solenoid valves
  - Inline ball valve



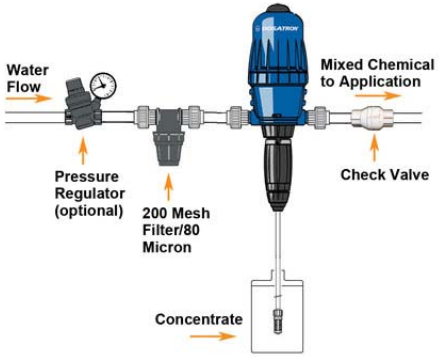
Irrigation Materials

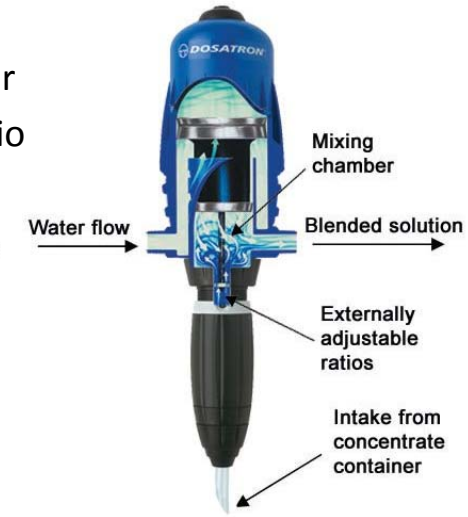
- **Emitters**
  - Pressure Compensated
  - Button type
  - Tube type



Fertilizer Injector

- Dilute concentrated water soluble fertilizer
- Adjustable mixing ratio





Environmental Control

Manual Controls

On/Off Switches

- Heater, Window, Light, Curtains, Solenoid, …

Timer Based Controls

Computer Integrated

Model-Based

ICT Technology

Sensors and Data logger

- **Data logger**
  - an electronic device that records data over time
  - built in or external instrument or sensors
  - also controlling options

Continuous Environmental Measurement & Control

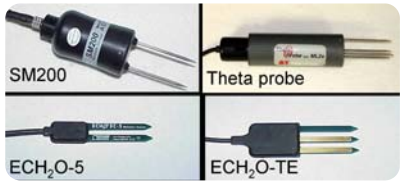
Sensors and Data logger

- **PCB**
  - Printed Circuit Board
  - Mechanically supports and electrically connects
- **Arduino**
  - DIY Style Microcontroller board
  - Open-source hardware and software

ARDUINO

Environment Measurements

Sensor → Data Process → Control → Research



Sensor Output?

Temp & RH sensor

PAR(PPFD) sensor

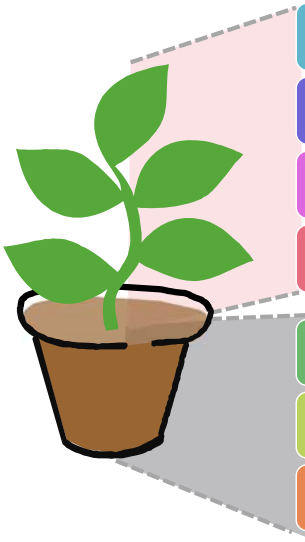
Load cell sensor

%Relative	Output (VDc)	Temperature(℃)	Output (VDc)
			0.000
95%	4.28	55	2.672

Calibrate

- mark with a standard scale of readings
- correlate the readings of (an instrument) with those of a standard in order to check the instrument's accuracy

Plant Production with ICT



- **Light** • LED Technology
- **Temperature** • AC / Heating / Vent
- **RH / VPD** • Dehumidifier / Air
- **CO_2** • CO_2 Fertilization
- **Moisture** •
- **Nutrition** •
- **O_2 & Gases** •

Soil Moisture Sensors

ICT for Horticulture Production