



ROYAL GOVERNMENT OF BHUTAN
Agriculture Research and Development Centre
Bajo: Wangduephodrang
Department of Agriculture
Ministry of Agriculture and Forests



Training manual on installation of irrigation and greenhouse automation



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(Developed during the Training of Trainer (ToT) conducted at ARDC Bajo with financial support from FAO-TA (FSAPP) and submitted to FAO as part of ToT agreement)

By

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1. Background:

Agriculture faces a great challenge in coping with growing water scarcity and increasing demands for food production. Various initiatives are being made to increase the efficiency of agricultural irrigation system. With the increased availability of Internet of Things (IOT) and Information and Communication Technology (ICT) it is now possible to real time monitor/control different processes of irrigation and water management in agriculture. Smart irrigation system is basically using water saving technologies such as micro-irrigation system combined with different IoT based technologies for automation. This manual is designed for one week basic training course on smart irrigation and greenhouse automation systems for field extension officers. It is designed to provide both theoretical background information on different aspects of irrigation and greenhouse automation technologies and practical skills through hands on training in the real field conditions. The content and structure of this manual has been developed and tested through fieldwork involving Agriculture Researchers from ARDC Bajo and Agriculture extension officers from Dagana and Wangduephodrang dzongkhags for one week duration at ARDC-Bajo through FAO financial support.

2. Learning Outcomes:

- I. Design, installation and maintenance of water efficient irrigation technology such as drip and sprinkler in the farm
- II. Demonstrate knowledge (theoretical and practical) on the application of SMART irrigation software (mobile apps) and hardware that are currently promoted in the country
- III. Develop and demonstrate skill on application of various greenhouse automation technologies in the field

3. Course outline and content:

Day wise course outline and topics to focus are presented below:

Days	Course content	Objectives	Mode of teaching
Day 1	<i>Morning: (Theoretical session)</i> <i>Principles and concepts of water Saving technologies</i> • Importance water resources in agriculture • What is water saving technologies? • Types of water saving irrigation system <i>Automation of the irrigation system</i> • Basic components of smart irrigation • ARDC-Wengkhari developed SMART controller features • Use of rule based and AI (Artificial Intelligent) Chatbot in agriculture automation	To understand the basics of water-saving technologies and automation	Lecture / Ppt presentations with diagrams, graphics and illustrations

	<i>Afternoon: (Theoretical session)</i> Principles and concepts of greenhouse automation • Basic principle of automated climate control in the greenhouse • Sensor and actuators used in the greenhouse • Climate control: Temperature • Climate control: Humidity • Climate control: CO₂ • Climate Control: Light • Irrigation automation in the greenhouse	To understand the basics and types of greenhouse automation	Lecture / Lecture / Ppt presentations with diagrams, graphics and illustrations
Day 2 and 3	<i>Practical and theory</i> • Basic plumbing tools and usage • Trenching and layout of mainline and lateral drip lines in citrus and avocado orchard • Basic pipe line fittings and accessories for drip irrigation for orchard • Practical session on making hdpe pipe joints (tee, Y and elbow) • Practical session on fitting and layout of mainline and lateral lines in citrus and avocado block	To understand and get plumbing practical skills required for installation of micro-irrigation	Field based lecture and demonstration
Day 4	<i>Theory and Practical</i> • Basic functions of components used • Practical session on making watering zones with CPVC pipe and fittings • Practical session on installation of main filter • Practical session on installation of main filter • Practical session on installation of 6 mm takeoff, extension tube and button drippers in citrus and avocado block • Testing and measurement of the flow rate of button drippers	To understand and get practical skills required for installation of micro-irrigation	Practical / Demonstration
Day 5	<i>Theory and Practical</i> • Physical installation of solar panel, charge controller, battery and smart irrigation controller • Installation of rain sensor and fertigation devices • Installation and configuration of internet connection through wi-fi modem • Smart irrigation software (mobile apps) configuration and usage • The exercise on interfacing and testing	To understand and get practical skills required for installation of micro-irrigation To get theoretical knowledge and practical skills for configuration and	Field based lecture and demonstration Field based lecture and demonstration

of smart irrigation mobile apps with the hardwires that are being setup in the field

usage of smart irrigation mobile Apps and software

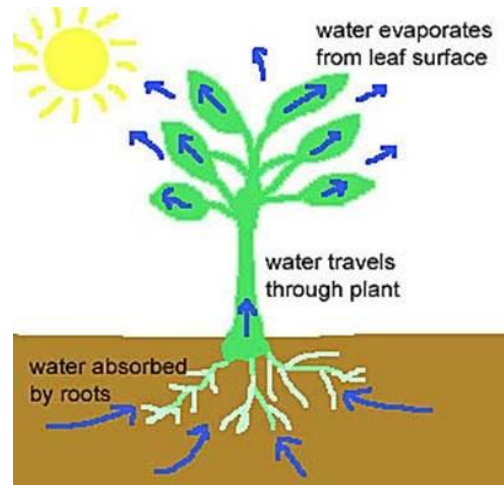
Day 6 *Theory and Practical on greenhouse automation*

- Practical session on fitting and layout of mainline and lateral lines for production of high value vegetables such as chili and tomato under greenhouse condition
 - Installation of automation of irrigation
 - Installation of ventilation fan, fogger and heating system to regulate the environmental control inside the greenhouse
 - Installation and configuration of automation device and software
 - Testing of the device and software
 - Installation of portable sprinkler irrigation system in the vegetable
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4. Principles and concepts of water Saving technologies (Theory session)

a) Importance of water resources in agriculture

- Water is most an important ingredient for photosynthesis of any plants
- It should be supplied to the soil just to satisfy its field capacity above which the water being supplied is a waste
- 70% of the world's fresh water resource is used by agriculture sector where 60% of the water is wasted due to inefficient irrigation system (FAO, 2014)
- Bhutan has abundant water resources with per capita availability of 94,500m³ (NEC 2018) but water availability at local scale (farm level) is very low which is less than 15000 m³
- Most of the irrigation and drinking water sources are seasonal and depends on monsoon rain
- Most water sources are trapped from small local catchments which has low reliability, quantity and quality as well
- Infrastructures and management are poor and inadequate. *Bhutan is economically water stressed country*



b) Different water saving technologies

What is micro-irrigation? Micro-irrigation system is a modern method of irrigation in which water is usually delivered in the form of discrete droplets, continuous drops and streams to minimized water wastage

Types of micro-irrigation system

- I. Sprinkler irrigation system:** Water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. Water efficiency is very high i.e. about 80%. More land can be irrigated by less water. Protects soil & crops from extreme weather conditions such as frost. Uniform application of water and preservation of soil erosion

Types of sprinkler system: Based on precipitation

- *Low volume sprinkler:* Precipitation less than 13 mm/hr
- *Medium volume sprinkler:* Precipitation 13-25 mm/hr
- *Large volume sprinkler:* Precipitation more 25 mm/hr



Based on sprinkler head types

Rotary head sprinkler: When operating, sprinkler heads rotate from side-to-side. Used for larger landscape areas because they have an average radius of throw between 15 and 50 feet. Examples

- wobbler mini sprinkler: Vegetables, Lawns, fodders, Nurseries
- Inverted mini wobbler sprinklers: In greenhouse productions, Mushroom cultivation
- Xcel- wobbler sprinkler: Orchards, Lawns, fodders
- Impact sprinkler



Spray head sprinkler: Nozzle and an adapter on a fixed piece of pipe and steady spray of water over area. Used to irrigate smaller areas because their area of coverage is between 5 and 15 feet.

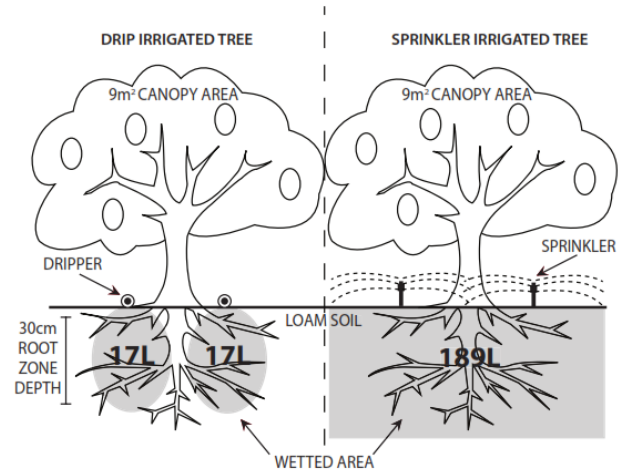
Bubbler's sprinkler: Bubbler sprinkler is a localized, low pressure, solid permanent installation system used in tree groves. Flow rate 100-250 L/hr



II. **Drip irrigation:** Drip irrigation or trickle irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. Introduced in late 1960's to early 1970's after the introduction of plastic pipe

Advantages:

- Supplying water where it is needed and has high efficiency greater than 90%
- Small wetted area (less evaporation)
- No runoff (reduced soil erosion)
- Good water distribution uniformity
- Less water required, unaffected by wind, etc
- Reduce weed growth
- Fertilizer can be mixed with drip irrigation and applied directly to root zone increasing the efficiency of the fertilizer:



Basic components of drip irrigation

- Water source with gravitational or pump push
- Control valve (manual or automatic)
- Filter
- Main line and sub-main lines
- Laterals lines
- Drip emitters

Solenoid valve: It is an electrically controlled valve to turn ON or OFF to regulate the flow of water in the pipes. Different size of solenoid valve available (32-110mm). Normally use 32 and 50 mm size in agriculture



Filter and accessories: A filter unit cleans irrigation water impurities that are suspended and prevent blockage of drip lines. Different flow rates (6-25 meter cube per hour) are normally used in agriculture. Screen filter consists of perforated cylinder placed in a plastic or metallic container. 100 to 200 mesh screens are available



Mainline, Sub-main and lateral lines: HDPE pipes 32mm, 25mm and 20mm with 8-10 PN pressure

Drip emitters: are the heart of any drip irrigation system. Emitters are the end devices which deliver water to plants in a specific manner. By understanding the differences in emitter types, users can more easily select the right emitter for any application.



Drip emitter types:

- Button drip emitter
- Inline
- Stake drip emitter

Flow rate of the emitter: 2.1 LPH (liter per hour), 4 LPH, 8 LPH, 12 LPH etc.,

Pressure compensated emitter (PC): emitter that maintains the same output at varying water inlet pressures. Therefore, PC drip emitters compensate for uneven terrain, length of supply tube and varying inlet flows

Non-PC emitter: The output flow rate varies with water inlet pressure

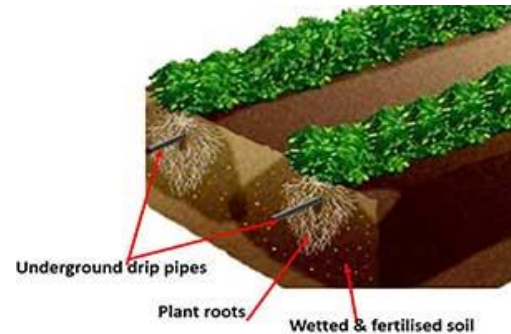


Inline Drip system



III. **Sub-surface Drip irrigation (SDI)**

- Applies water to plants from below the soil's surface or underground
- Tubes and pipes are hidden under the soil near the root zone for water delivery, no wastage of water
- Minimize the water loss through evaporation
- Minimize damages of main and lateral drip lines by physical disturbance and UV deterioration
- Protect from extreme climate (hot or cold)



IV. **Watering zones:** Dividing the irrigation system into two or more areas in order to increase the efficiency, minimize water waste, and improve the health of the plants

- Zoning might be desired if you have plants with very different watering requirement
- Zoning might be required if the number of plants and their cumulative watering needs exceed the capacity of the water input supply



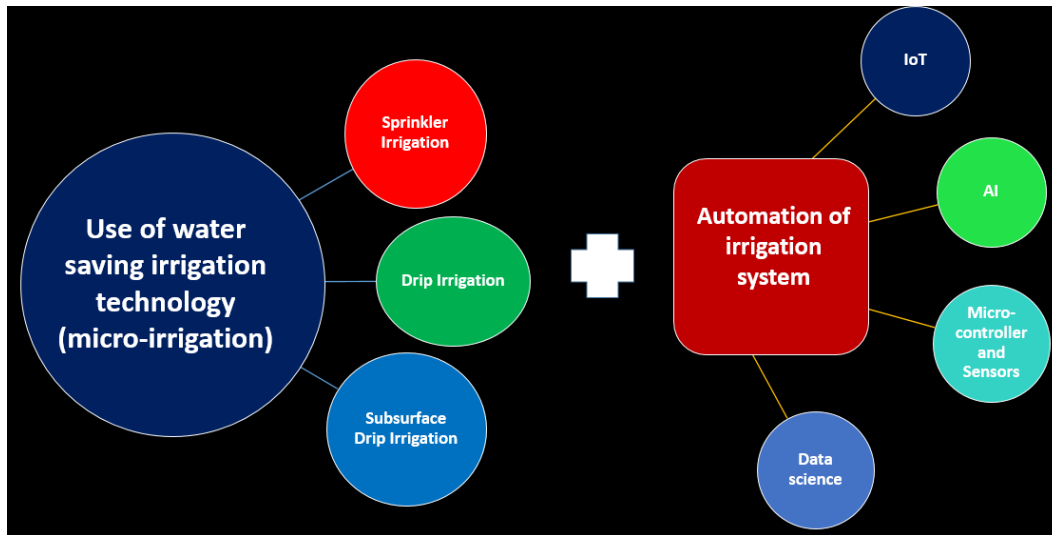
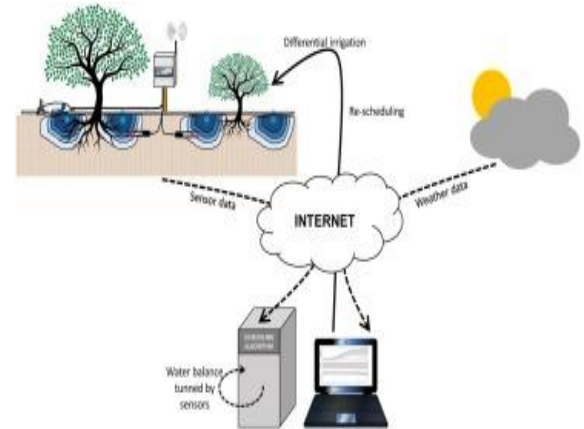
5. **Automation of Irrigation system**

The operation of the system with no or just a minimum of human intervention.

Objectives:

- To increase the efficiency of irrigation system
- To minimize the labor shortages and input cost in irrigation
- To increase crop yield per unit area

Basic component of the smart irrigation system are as follows:



I. **SMART Irrigation Controller:** Irrigation controllers are the brains of the Irrigation system which control the irrigation valves and pumps. The valves regulate the flow of water in the irrigation system.

II. **ARDC-Wengkar developed SMART controller features:**

Hybrid of timer, IoT and sensor based SMART irrigation controller. Developed from on open-source firmware and hardware resources

- Much cheaper compared to many other commercially available similar controllers
- Open-source hardware and software: can be modified/alterd freely to suite our needs without any restrictions..... Closed source or proprietary technologies needs specific trained technical person for installation and maintenance of the system. The modification of hardware and software are prohibited ...promotes technology consumption rather than technology innovation
- It has capacity to irrigate large agriculture land. The cost effectiveness of the system increases with the increase of areas under irrigation



- It uses real time climatic data such as temperature, humidity, rainfall and soil moisture to control irrigation system.
- The irrigation system can be managed and monitored remotely through local area network or worldwide access with use of other IoT platforms
- The system can be installed in any remote areas as the system can be directly powered from solar power
- The same system can be also used in municipals for efficient water management especially for distribution, scheduling and pumping purposes

Estimated Material cost in 1 acre orchard (Drip system)

Items	Quantity	Unit	Rate	Total (Nu)
Automation equipment and accessories				
8 ports wifi-internet based SMART irrigation controller	1	nos	52000	52000
Solar panel 50W	1	nos		
Battery 18 AMP/h	1	nos		
Charge controller 10 amp	1	nos		
Electric Valve (24-12 V AC, DC),	3	nos	5000	15000
3G or 4G WIFI modem with SIM and data for 1 month	1	nos	6000	6000
Pipe line, dripper and accessories				
32 mm Druk HDPE pipe, PN-10 or 8	200	meter	65	13000
20 mm Druk HDPE pipe PN-10	1200	meter	35	42000
6 mm extension tube	350	meter	12	4200
6 mm screw takeoff	500	nos	6	3000
Pressure compensated drippers (2.2 LPH or 4LHP)	300	nos	12	3600
12 M cube, 100-micron irrigation filter	1	nos	4600.00	4600
Accessories for connecting valves and controller	1	set	12000	12000
Total (Nu)				155400

III. Use of rule based and AI (Artificial Intelligent) based Chatbot in agriculture automation

What is Chatbot?

- A Chatbot is a application software or device used to conduct an on-line chat conversation via text or text-to-speech. Simply “Chatting Robot”
- Messaging Apps such as Facebook, WhatsApp and Telegram etc.,

Types of Chatbot

Rule-based chatbots:

- Chatbots without AI (Artificial Intelligence) functionality. They just follow pre-designed rules in the program and easy to develop and deploy

AI based chatbots:

- Machine learning Chatbot which can learn and improve their ability from interactions with users over a time. Not very easy to develop as it needs lots of time to train and test the Chatbots

Features of ARDC-Wengkhair Developed Chatbot

- Rule based and access via Telegram messaging apps. Individual or group access. Alert and notification

Supported Sensors:

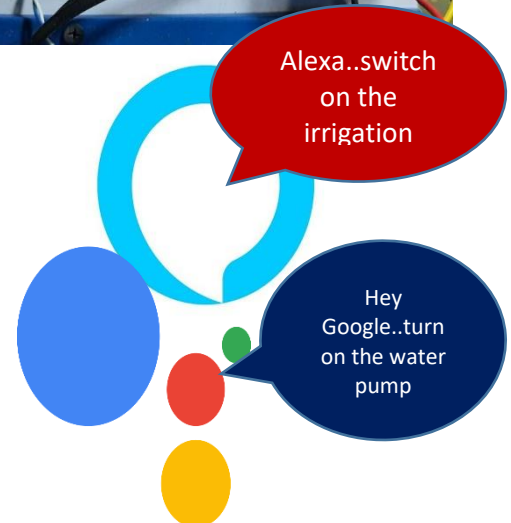
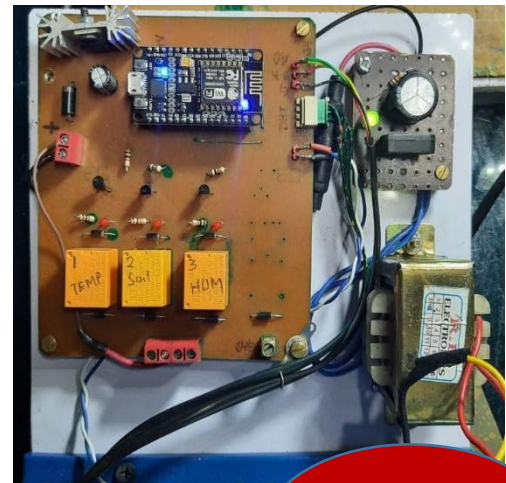
- Temperature and Humidity sensor. Soil Moisture sensor and Webcam

Supported Actuators:

- Electric valve for irrigation, Switches to turn on/off of exhaust fan and heaters

AI (Artificial Intelligent) based Chatbot

- Today's technologies like Siri, Alexa and Google Assistant are virtual assistants based on AI conversational bots
- These technologies are powerful yet very simple to setup for home automation purpose including irrigation automation and water management

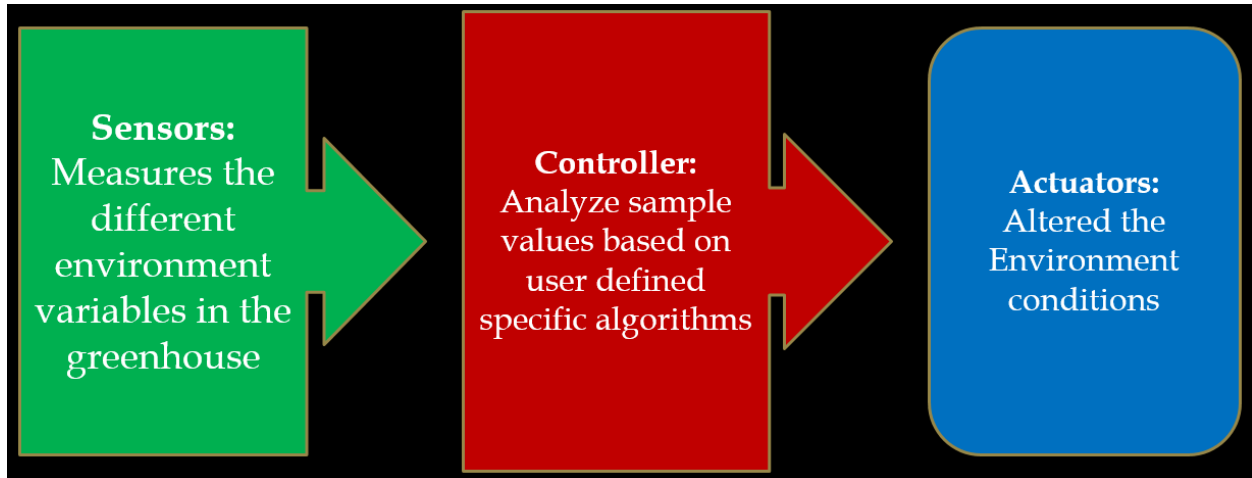


6. Principles and concepts of greenhouse automation

Objectives:

- Control greenhouse environment (Temperature, Humidity, Lighting, CO2) to create an ideal climatic condition for plant growth
- Reduction of operation cost like labor and other input cost (nutrient, water and electricity)

Basic principle of automated climate control in the greenhouse are as follows:



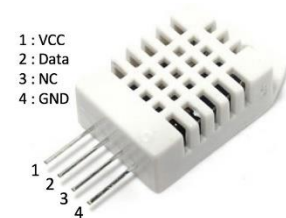
Sensors

- Electronic device or module that detect events or changes in its environment and send the information to the controller
- Activation or deactivation of different actuators
- Readings from these sensors are also displayed on a dashboard for monitoring

Types of sensors

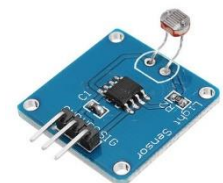
Air temperature and humidity sensor module:

- An analog or digital sensor to detect changes of air temperature and humidity inside the greenhouse structure.
- The readings from these sensors are used for activation of different actuators



Light sensor:

- Light sensor detects the ideal lighting conditions of the plants in the greenhouse.
- It detects the brightness and intensity of light and controls the activation or de-activation of artificial lighting system if present



Soil moisture sensor:

- Moisture sensors detect and monitor the moisture level of plant root zones.

- The data from these sensors are sent to the irrigation controller to activate or deactivate the solenoid valve of irrigation

Carbon dioxide (CO₂) sensor:

- The CO₂ sensor module are used to monitor the level of CO₂ concentration in the greenhouse.



Actuator

- An actuator is a part of a device or machine that is to achieve physical movements
- It is operated or activated based on the sensor values by the main controller.

Types of actuators

Water pump: AC and DC Pumps, Submersible and Non-submersible

Solenoid valve:

- It is an electrically controlled valve to turn ON or OFF to regulate the flow of nutrient solution. It automatically controls the distribution network of nutrient and water circulation.

Electric heater:

- Heaters are electric-powered used for providing heat during winter months.

Electric fan:

- It is generally used for ventilating and cooling the structure.
- The most critical electric fan used in the greenhouse is exhaust fan for removing accumulated heat and moisture

Controller device:

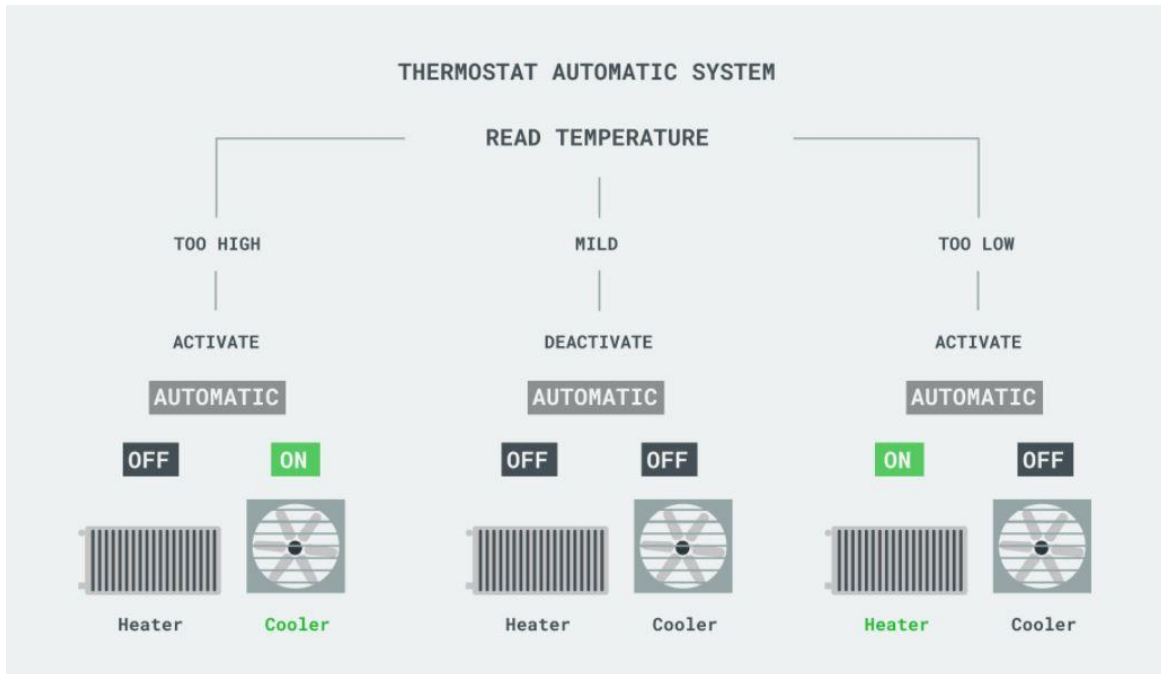
The main function of the controlling device is to acquire readings from different sensors, analyze data and control pre-set parameters with the help of different actuators present in the system.

Remote monitoring is also one of the main functions of the hydroponics controlling device

I. Climate control: Temperature

- Temperature parameter is the primary focus of most climate control systems in the greenhouse
- It is dynamic and very difficult parameters to control
- It is economical to control the extreme temperature instead of ideal temperature
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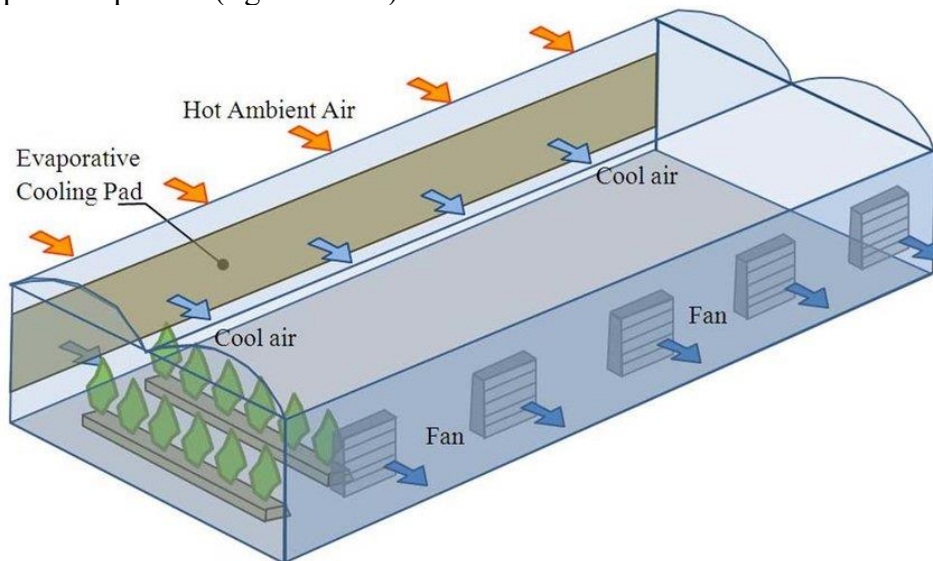
Automated temperature control method as below



Climate control: Cooling

Evaporative cooling system:

- The process of evaporation requires energy (2400 kJ/kg) which is extracted from air and results cooling of the air
- Effective in climates where outdoor relative humidity (RH) is less than 60%
- Evaporative pads at one end of the greenhouse are kept wet and fans at the other end of the house pull air through the pads. Air entering the house is cooled as water in the pads evaporates (figure below)



Misting and Fogger cooling systems:

- An atomizer that produces water into minute droplets. The evaporation of this fog-like droplets cools the greenhouse.

Cooling through Automated vents system:

- Consist of panels that open and allow air exchange with the outside. Natural cooling

Energy Curtain or thermal screen cooling system:

- Automated curtains using fabrics that can insulate a greenhouse and shade the crops during the day

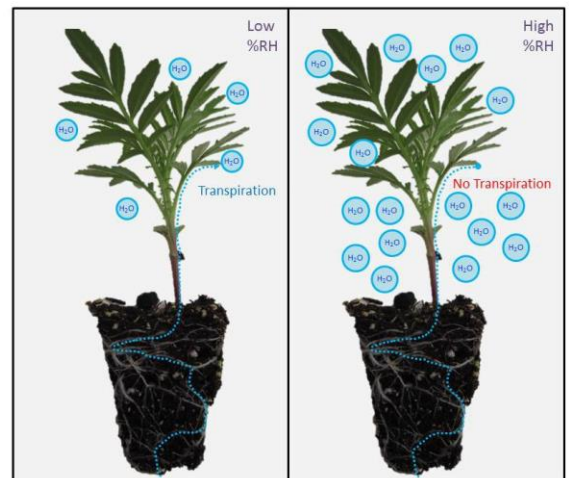
Climate control: Heating

Hot water heat system: Heating water in a boiler and pumping the hot water through pipes located in the greenhouse.

Electric heater with blower: Heat air within the unit, then blow the hot air throughout the greenhouse.

II. Climate Control – Relative Humidity

- Like temperature, plants have an ideal relative humidity range as well. Optimal values of RH are 60-80% for most plants
- Raising temperature reduces RH while lowering temperature increases RH
- If RH is very low, plants will transpire excessively, leading them to experience water stress
- When humidity is too high, the air become saturated with water vapor and make transpiration physically impossible. Transpiration is a crucial part of the plants' nutrient transport system

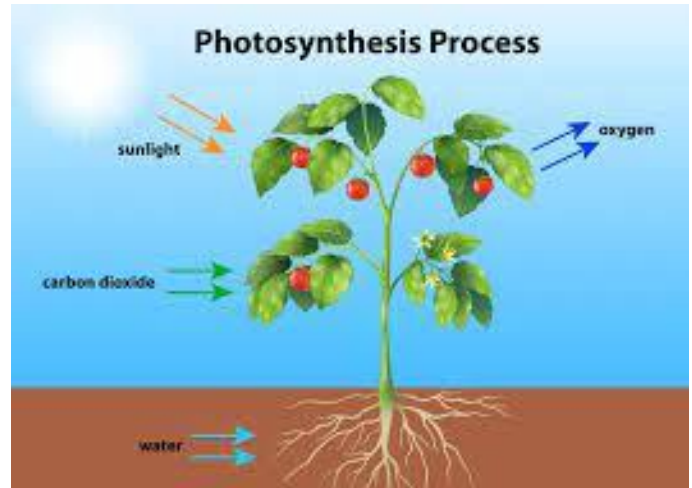


Low humidity control: Use of evaporative cool pad and fogger system

High humidity control: Use of ventilation, exhaust fan and de-humidifier devices

III. Climate control: Light/radiation

- The amount of radiation directly impacts the plants' ability to photosynthesize, develop and grow
- For indoor system, the artificial lighting system is necessary as plants have no access to the sunlight.
- For out-door system, artificial lighting may be provided if the light from the sun is not enough for proper plant development



Use of artificial light: *Grow-lights*

- Most plants use about 495 – 570 nm (Nano meter) range of visible light spectrum. Green parts of spectrum are reflected by chlorophyll.
- During the vegetative stage, plants require more of blue spectrum of light which has higher energy content.
- During flowering and fruiting (reproductive) stage, the plants require more of red spectrum light

Types of grow lights

Fluorescent tube: Florescent tube can be used as they are cheap, readily available in the local market. Provide full spectrum (white light) of light for the plants.

Compact Fluorescent bulbs (CFL): CFL light can be used as they are cheap, easy to use and readily available. CFL bulbs are available in different power ratings and sizes. Provides full spectrum light for the plants.

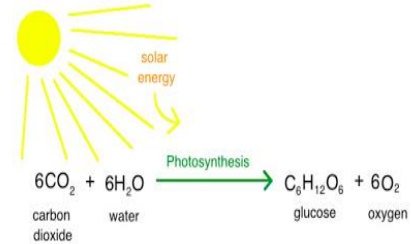
LED (Light Emitting Diode) lights:

- Considered to be the most efficient lighting system in the greenhouse system.
- They produce combination of blue and red light as required by the plants.
- LED grow lights are more energy efficient compared to other lighting sources
- Long lasting



Climate control: CO₂

- During photosynthesis, plants absorb CO₂ from the air to produce carbohydrates necessary for plant growth.
- Enriching the air with CO₂ can help plants grow faster
- Usually enrich the greenhouse environment to a level of around 1,000 ppm
- Normal carbon dioxide concentration in the air around 350 to 400 ppm



IV. Irrigation Automation in greenhouse

Drip irrigation with Spaghetti tubing: Automated system that involves small tubes connected to a main line

Capillary mats: consist of porous mats placed on a bench and wetted. The medium in the pots absorbs the water through capillary action.

Irrigation booms: Move across the entire bench and well-placed nozzles flood the pots below as they pass over the plants. Commonly used with bedding plants, plug trays, and some potted plants

Overhead sprinklers: Stationary sprinkler heads placed throughout the growing space. Large amount of water in a short period of time. Often used with bedding plant



Field work and practical session

1. **Hand-on training on handling of basic plumbing tools**
2. **Hands on training of installation of main and lateral lines for drip irrigation**
 - Design and installation of drip irrigation in fruit tree orchard and vegetable garden
 - Design and installation of sprinkler irrigation in fruit tree orchard and vegetable garden
 - Maintenance of drip and Sprinkler irrigation system
 - Basic understanding the function and usage of some of the important components of SMART irrigation system both software and hardware
 - Develop water scheduling for efficient water management using SMART irrigation mobile apps

Materials: SMART irrigation controller, Drip emitters of different flow rate and types, filters, connectors, HDPE pipes (20mm, 25 mm), Solenoid valves (25mm), copper wire, solar panel (50Watts), lead acidic battery (12V, 18A H), Temperature and Humidity Sensor, Soil moisture Sensor,

Tools: Battery operated Drill machine and drill bit sets, hand held metal cutter, multi-meter, Screw-driver sets, pipe wrench etc.