RE-ENGINEERING THE AGRICULTURAL ENVIRONMENT FOR WHOLE-YEAR ROUND PRODUCTION OF HIGH VALUE CROPS IN THE LOWLAND TROPICS


The prevailing hot weather condition during the dry months is now
prohibiting the production of many crops when planted in the open field.


Likewise, the occurrence of typhoon and strong winds during
the rainy months have the same detrimental effect


Pesticide infected crop in the open field

CABBAGE CROP IN THE OPEN FIELD UNDER GOOD WEATHER CONDITION

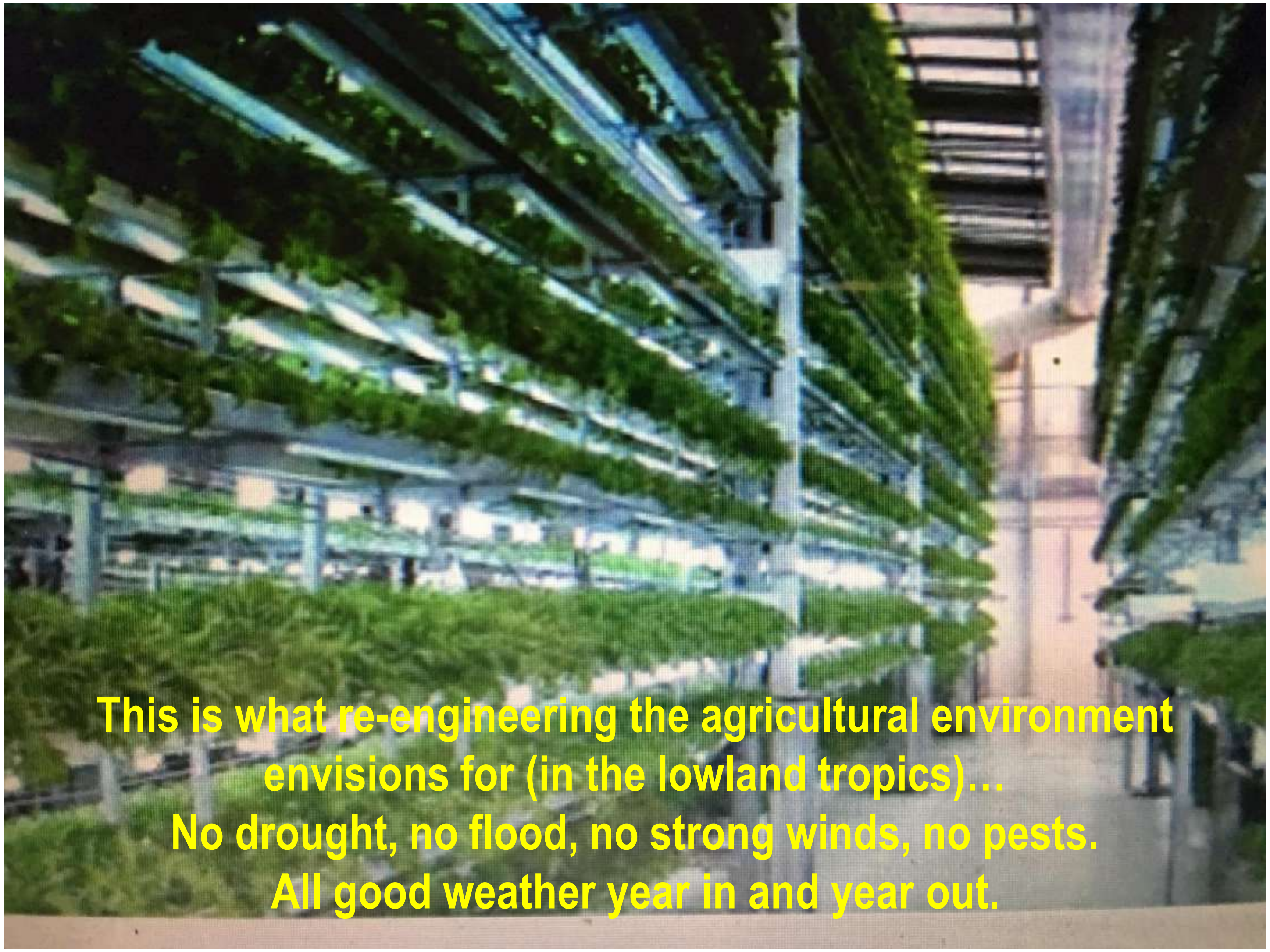
ISSUES AT HAND

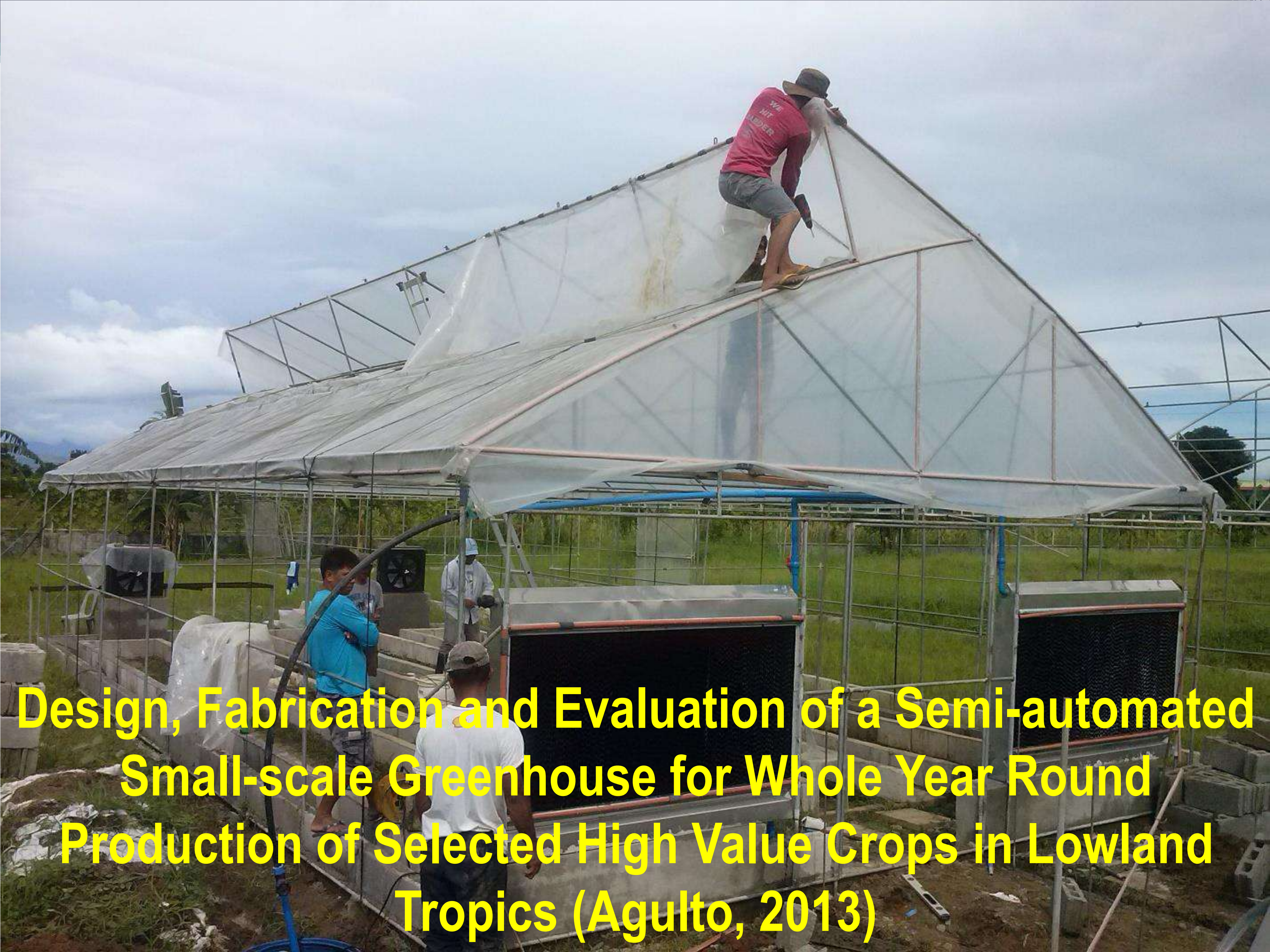
Climate change effects

Cropping intensity is season dependent

Reduction of farm areas due to commercialization and industrialization

Occurrence of pests and diseases


This is what re-engineering the agricultural environment
envisions for (in the lowland tropics)…
No drought, no flood, no strong winds, no pests.
All good weather year in and year out.



Design, Fabrication and Evaluation of a Semi-automated Small-scale Greenhouse for Whole Year Round Production of Selected High Value Crops in Lowland Tropics (Agulto, 2013)


Evporative coolers


Exhaust Fans

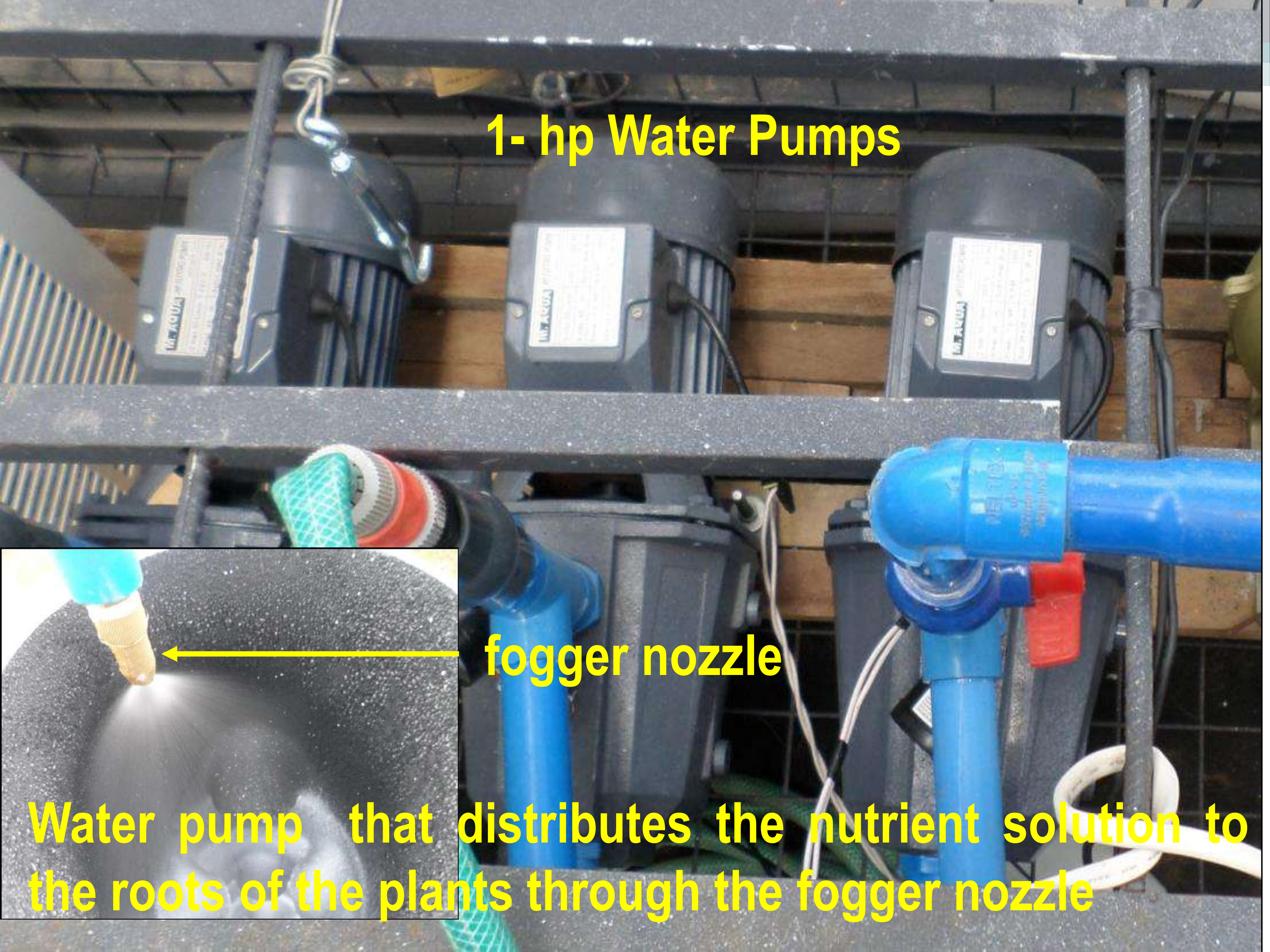
Bell pepper production inside the modified greenhoue in the lowland tropics

BELL PEPPER IN THE OPEN FIELD

BELL PEPPER INSIDE THE MODIFIED GREENHOUSE


Application of Ground Heat Exchanger (GHE) for Root Zone Cooling of Aeroponically-grown Strawberry) Plant Under Tropical Greenhouse Condition (Pascual, 2018)

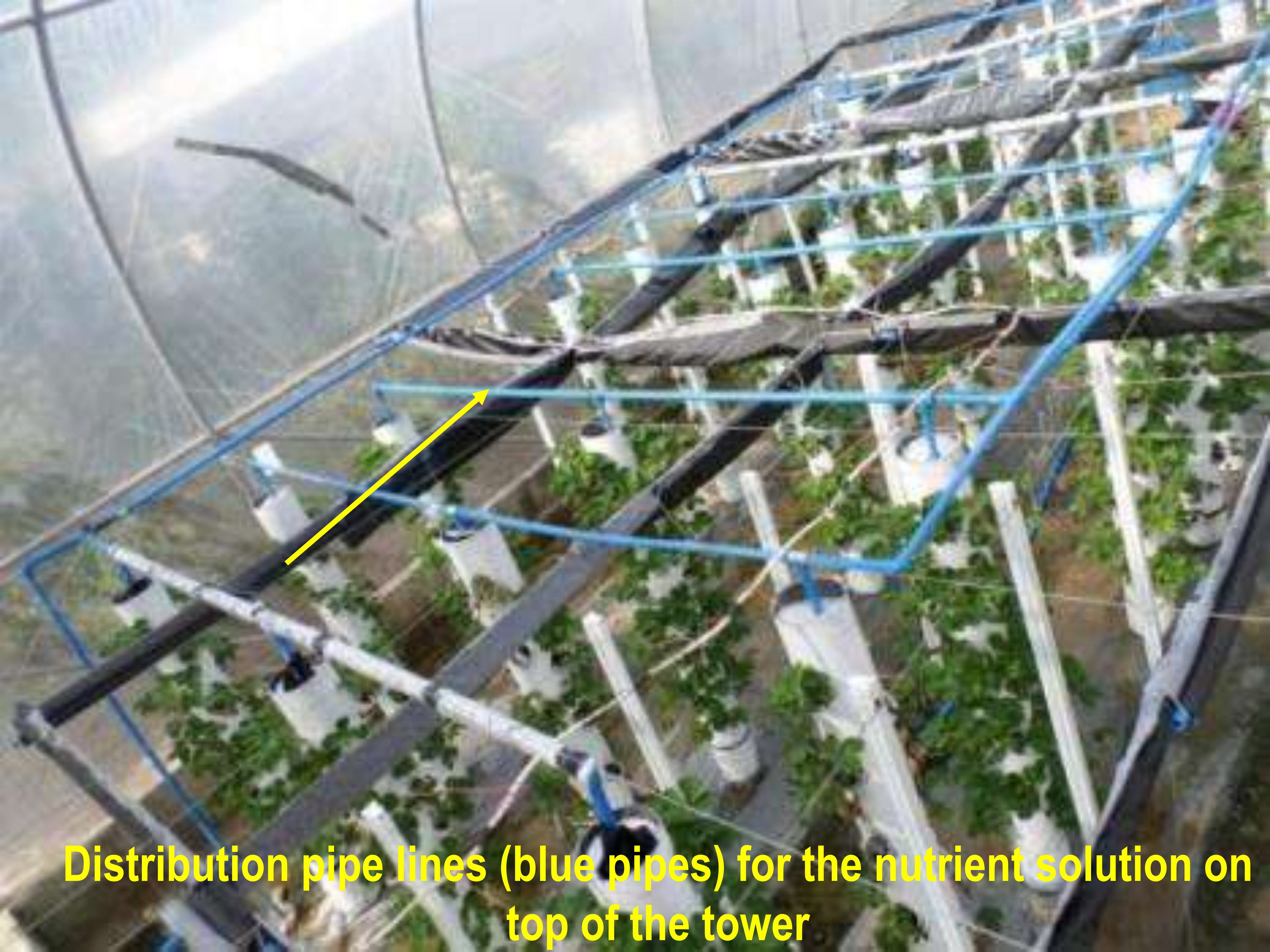

Greenhouse (6m x 12m, covered with UV plastic &
30% light reduction shade net) with
1. Ground Heat Exchanger (GHE) for Root Zone Cooling
2. Aeroponic System
3. Vertical Farming System
4. Lowland Condition


1- hp Water Pumps
fogger nozzle
Water pump that distributes the nutrient solution to the roots of the plants through the fogger nozzle


Cooling fan and blower
The blower forces air into the buried pipes for cooling the roots

Underground pipes where cooling of air takes place


Distribution pipe lines for air which also serve as base of the vertical tower and as return pipe


Distribution pipe lines (blue pipes) for the nutrient solution on top of the tower

Mesh Filter

- 200 mesh to filter impurities or any solid materials that may clogged the fogger/mist nozzle

Fogger Nozzle

- A sprayer nozzle to atomized the nutrient solution

Nutrient solution tank that collects the nutrient solution and back to the water pump for re-circulation.


Automatic Timer
-used to set the water pump operation at a desired frequency.
-15 minutes ON/30 minutes OFF during the night
- continuous operation from 8:00 AM – 5:00 PM

Net Pot and Substrate

- Improvised net pot (3” diameter
- Polyfiber to hold the plants in place)

PVC Pipe for Vertical Tower

- 4” black PVC pipe improvised as aeroponic tower (painted with white to minimize the heat build up)

LED lights

- 16-watts ECOLUM LED tube used to extend the photoperiod

Shade Net and Cover

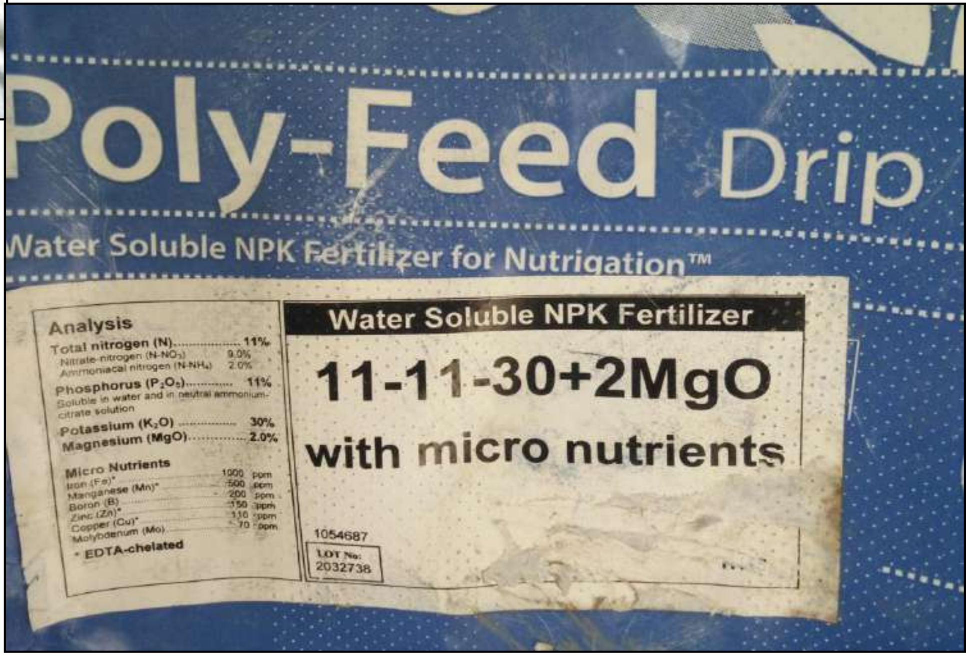
- 30% light reduction shade net
- black canvass to cover the lights to avoid influence on the other treatments

SNAP Nutrient Solution

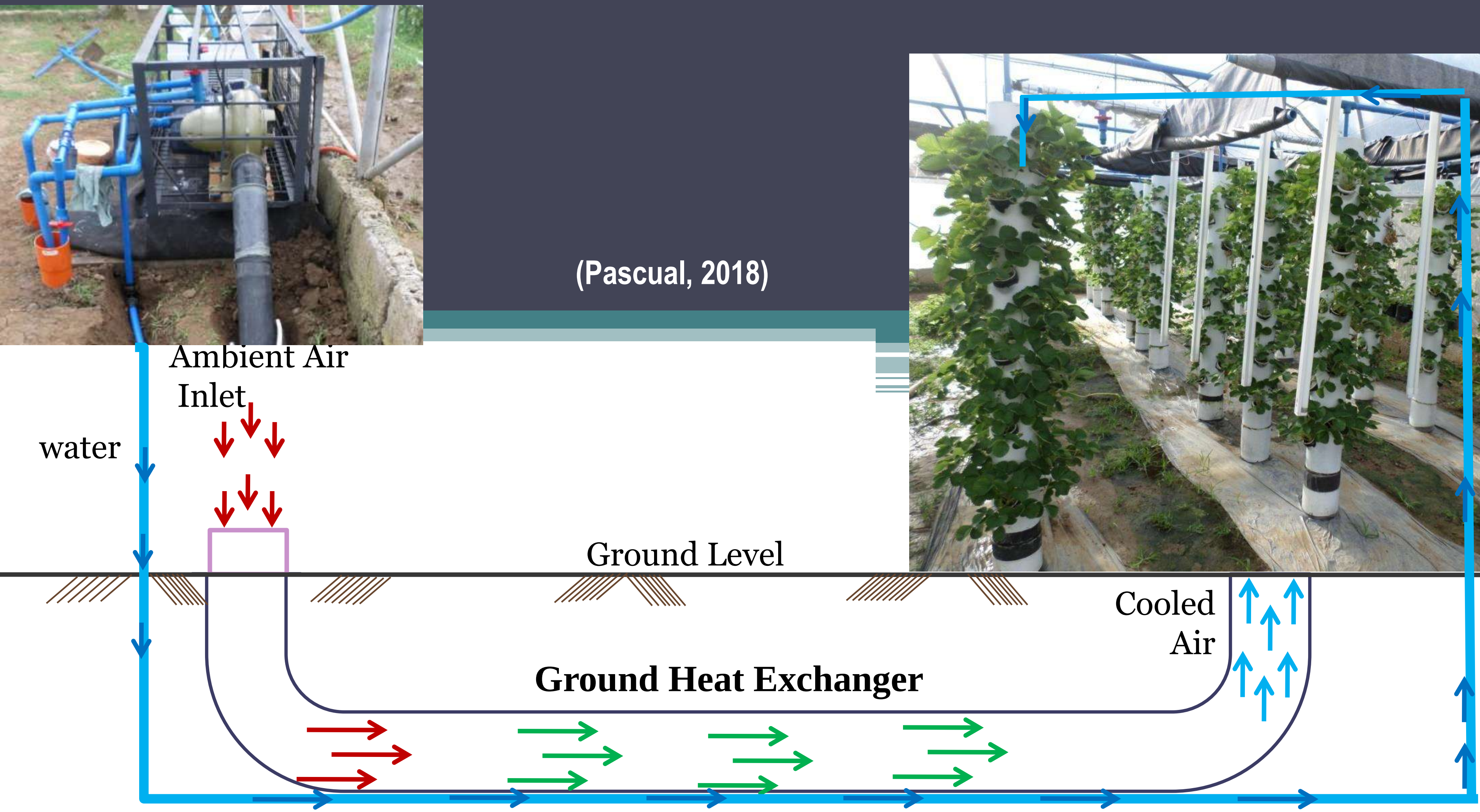
- nutrient solution during the vegetative growth (25 ml:10 li of water)

Granular water soluble fertilizer

- granular water soluble fertilizer during the fruiting stage
- Dosage is 1.5 g/l – 3.0 g/l to attain a 1.6 EC – 2.8 EC of the nutrient solution



Application of Ground Heat Exchanger (GHE) for Root Zone Cooling of Aeroponically-grown Strawberry *(Fragaria x ananassa)* Plant Under Tropical Greenhouse Condition



(Pascual, 2018)

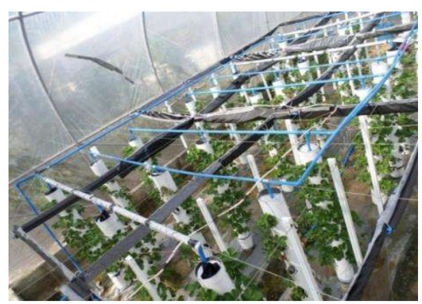
Harvested strawberry fruits inside the modified greenhouse in the lowland tropics using root zone cooling and vertical farming systems

The Ground Heat Exchanger System

A - Water pump and Blower

B – buried pipes for air and water flow

C – distribution line for air flow to the aeroponic tower



D – distribution line for nutrient solution to the roots of plants

E – return pipes of the nutrient solution

The Ground Heat Exchanger System

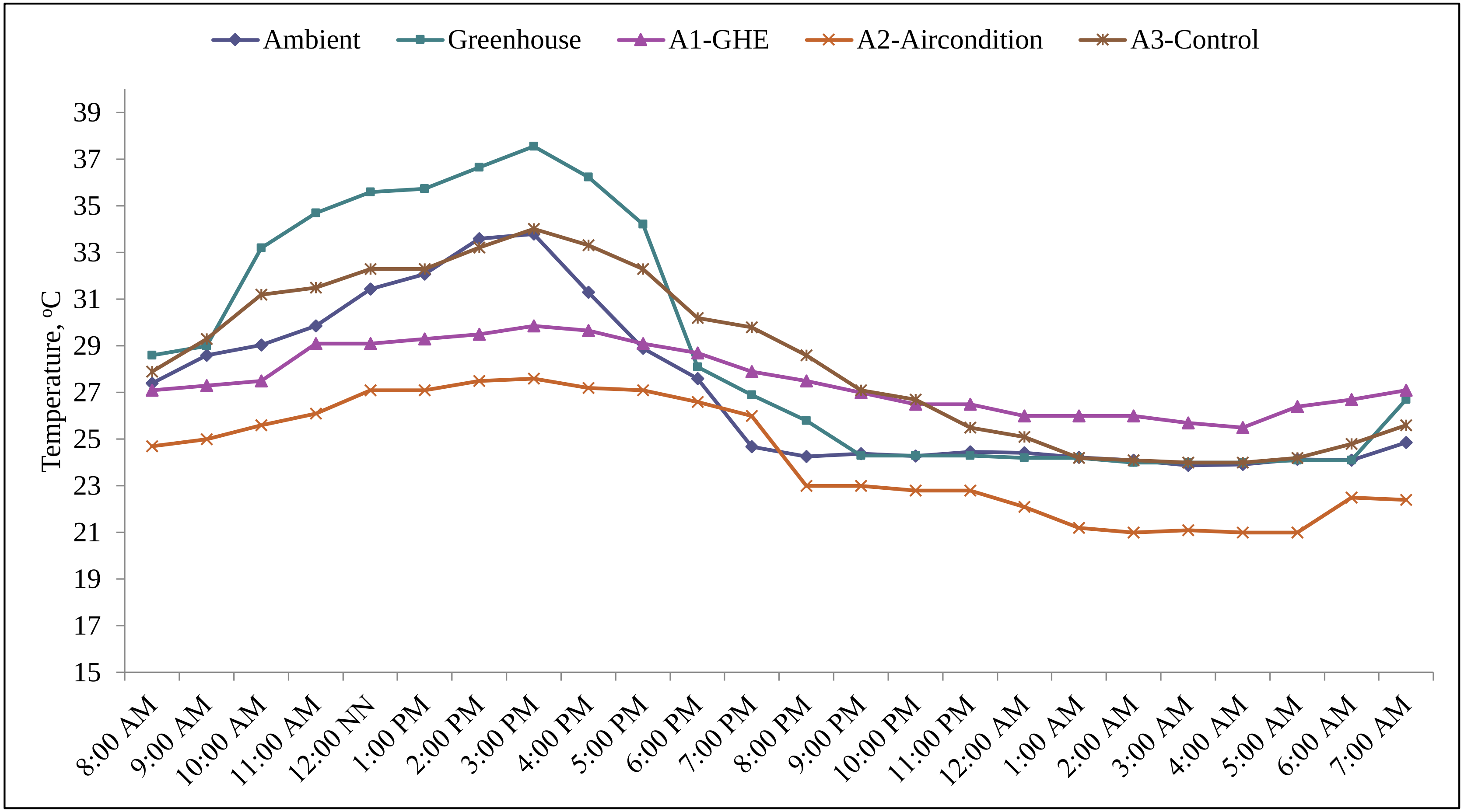
- Using this technology, the ambient temperature was reduced from an average of 28.05°C down to 26.75°C.

- With no root zone cooling, the root zone temperature averages 28.92°C but the fluctuation was more damaging to plants considering that the maximum and minimum recorded temperatures without cooling was 33.32°C and 26.00°C, respectively.

The Ground Heat Exchanger System

- With the ground heat exchanger, the root zone temperature was more stable with no incidence of rise higher than 30°C. Range is from 24.22°C – 29.50°C.

- Morgan (2006) mentioned that just a few minutes a day of root zone temperatures of more than 30°C will slow the growth of heat-sensitive crops such as lettuce and parsley.

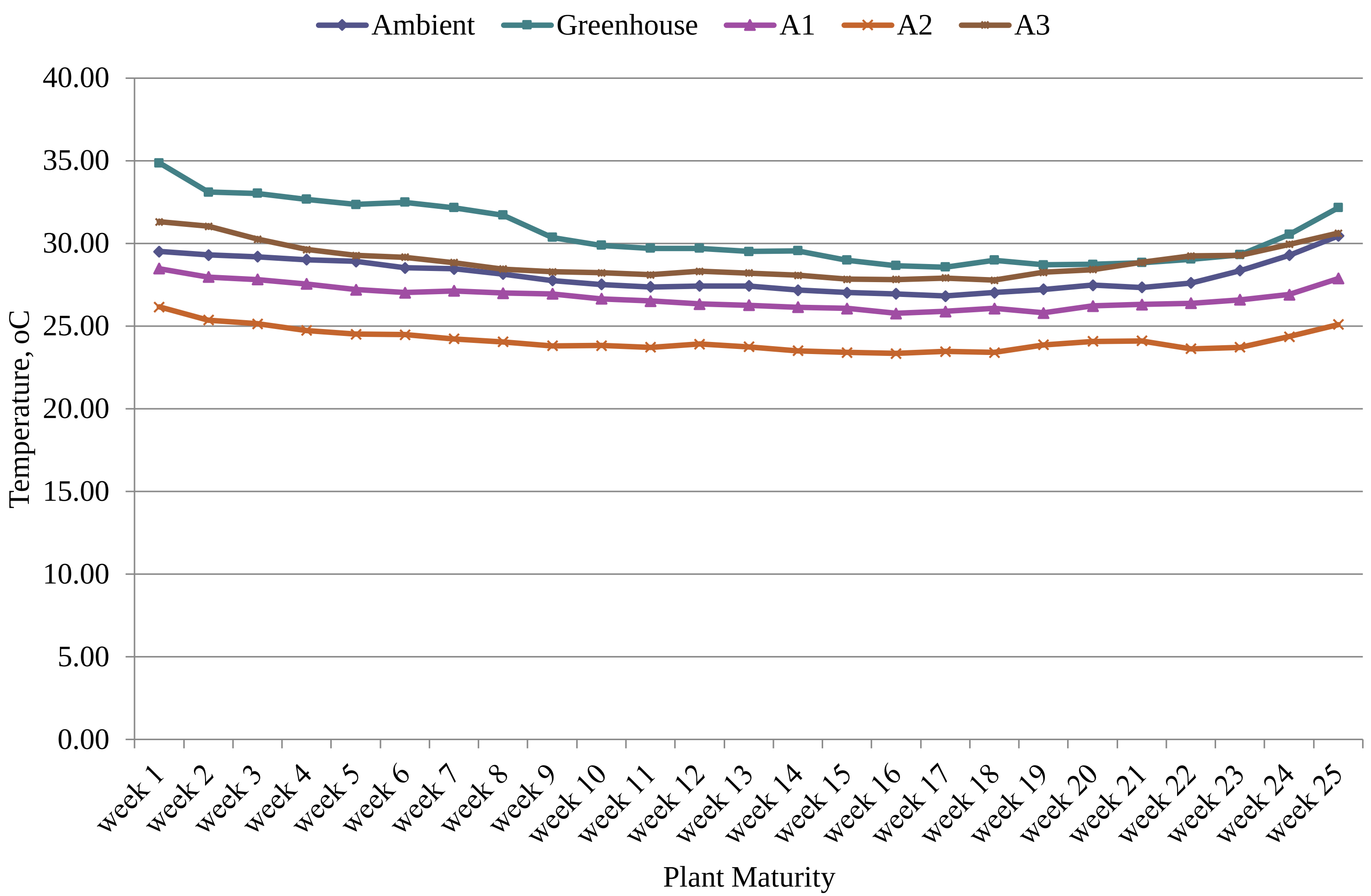


Temperature inside the greenhouse with root zone cooling and in the open field during pre-testing (24 hours) in the lowland tropics

Environmental Factors - Temperature

- The average ambient temperature during day-time (6:00 AM – 5:00 PM) was 30.60°C, while inside the greenhouse was elevated due to heat accumulation with an average of 34.15°C. Simultaneously, the root zone temperatures range from 26.50°C - 31.73°C, respectively.

- During night time (6:00 PM – 5:00 AM), temperatures were more stable for both the ambient and greenhouse with almost identical average of 24.52°C and 24.93°C, respectively. Consequently, treatments A_1, A_2 and A_3 root zone temperatures were lower with an average of 26.68°C, 22.60°C and 25.99°C, respectively

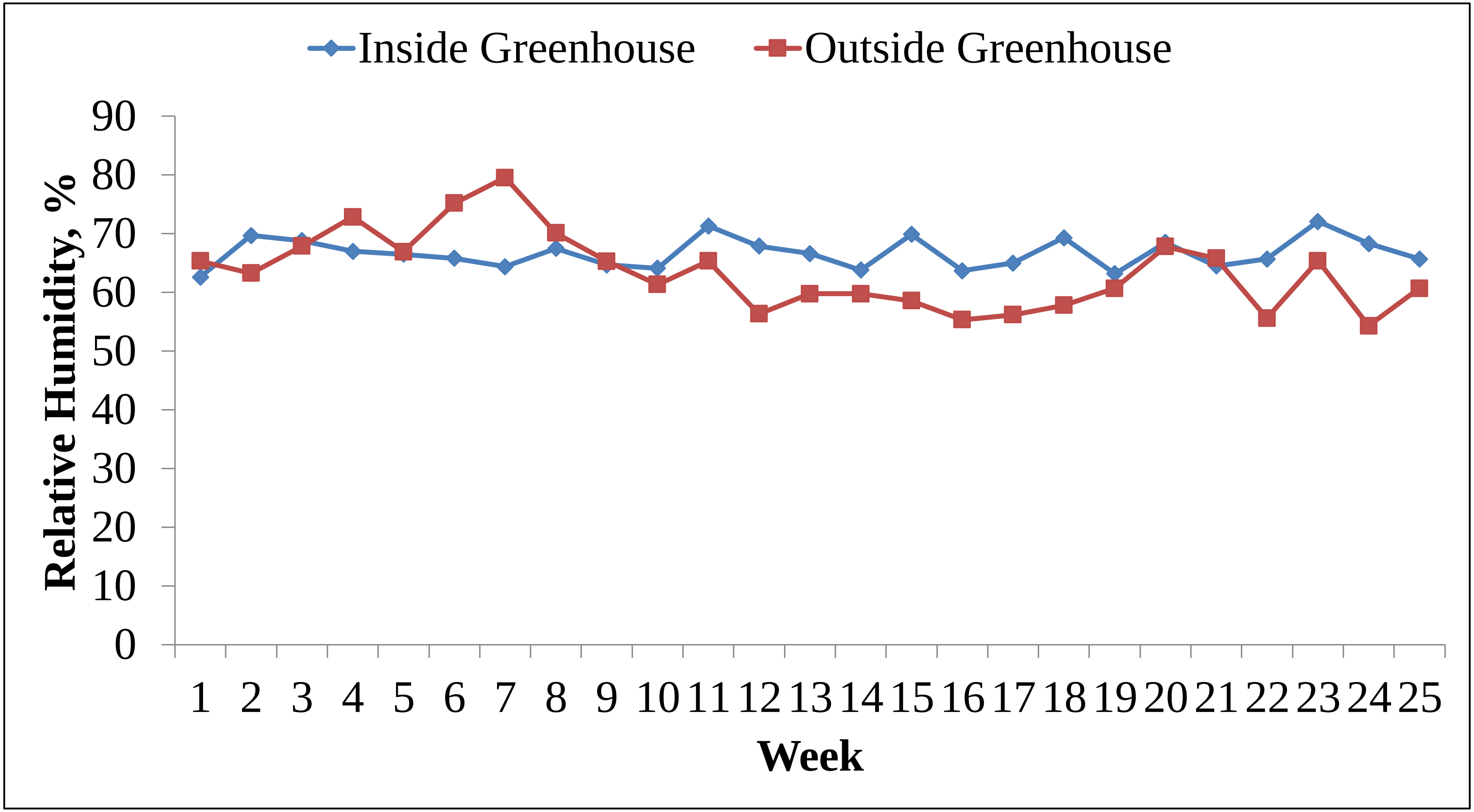


Weekly average temperature inside the greenhouse with root zone cooling and in the openfield during the growing period of strawberry in the lowland tropics

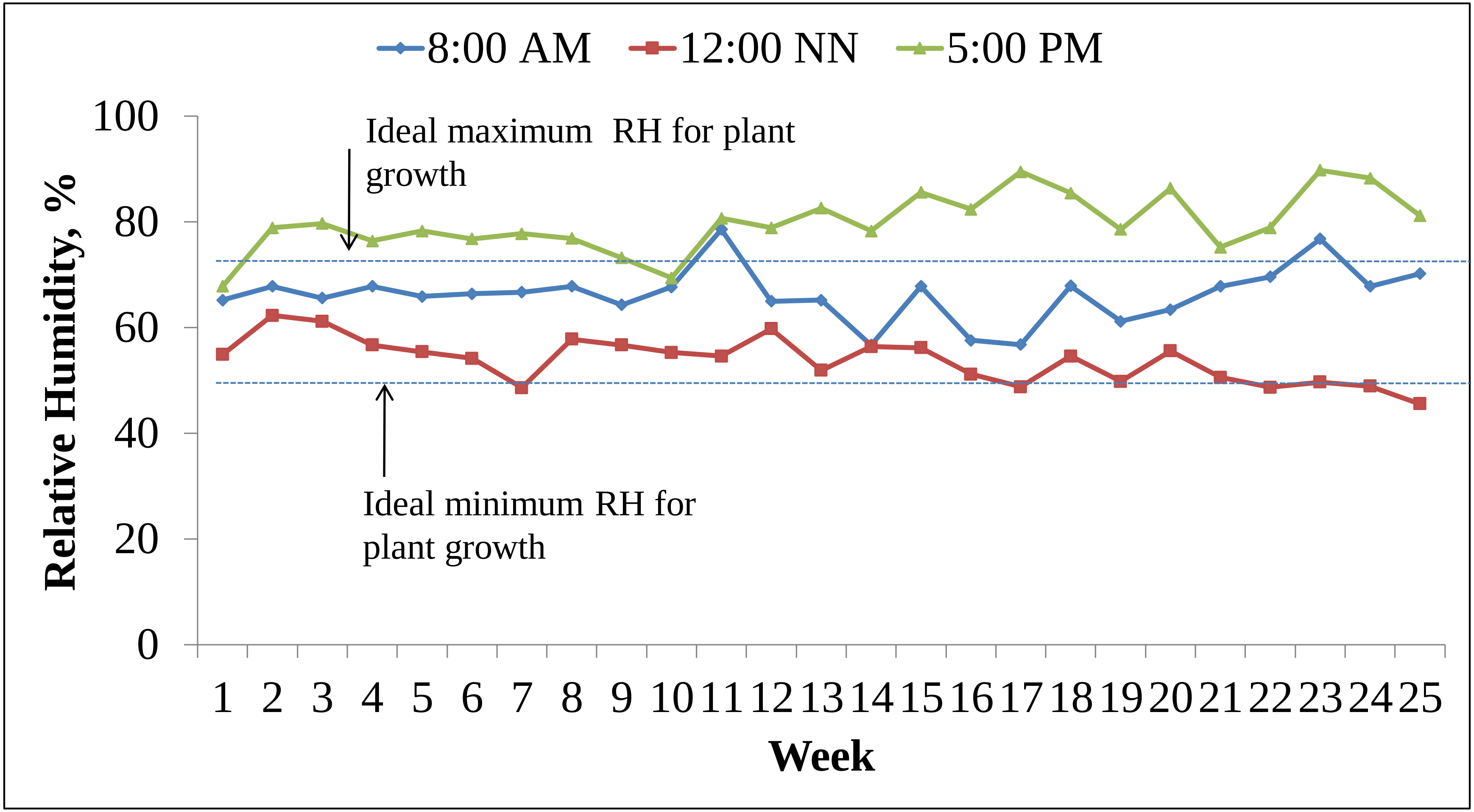
Environmental Factors - Temperature

- For the duration of the experiment, temperature reading was done three times a day (8:00 AM, 12:00 NN and 5:00 PM). The average ambient temperature during this period was 28.05°C while inside the greenhouse was highest at an average of 35.19°C.The average root zone temperatures for treatments A_1, A_2 and A_3 were 26.75°C, 24.14°C and 28.92°C, respectively.

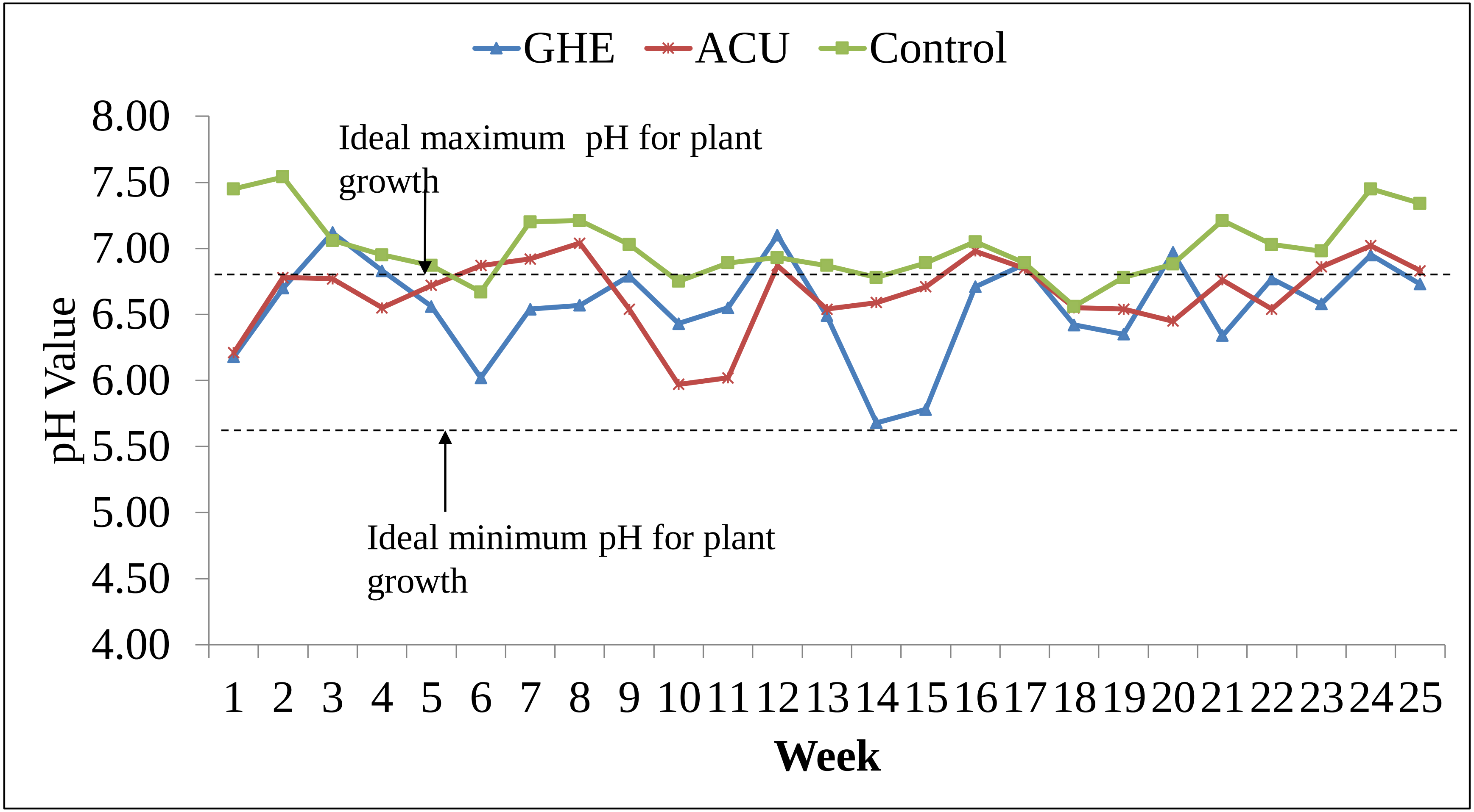
- The use of ground heat exchanger was effective in maintaining the root zone temperature to a maximum of 29.50°C. Although treatment A_3 had an average temperature of 28.92°C, the maximum and minimum temperatures recorded was 33.32°C and 26.00°C, respectively. Beauchamp and Torrance (1969) revealed that extreme fluctuation on the root temperatures has a negative effect on the growth and development of plants.



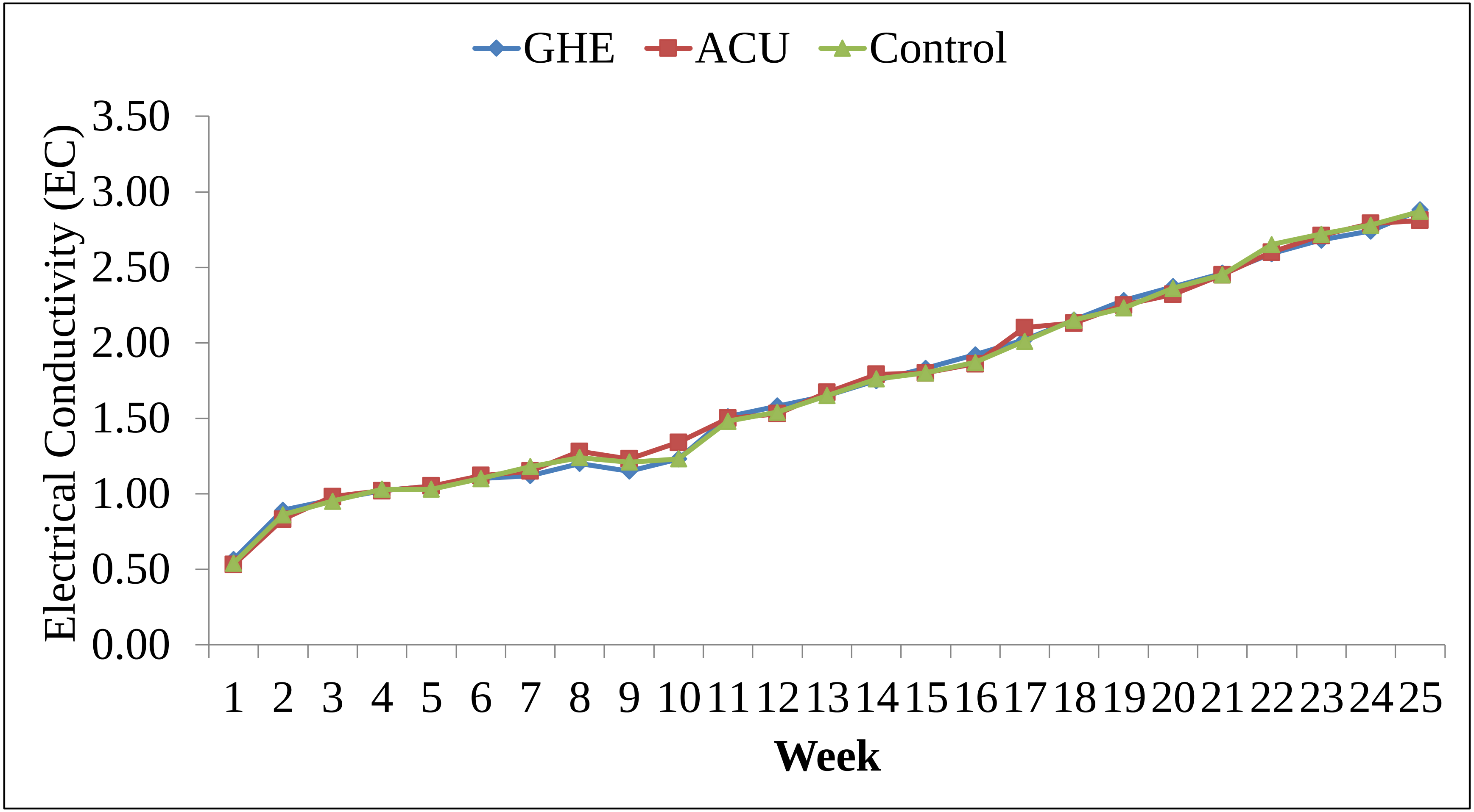
Average weekly relative humidity at different plant maturity



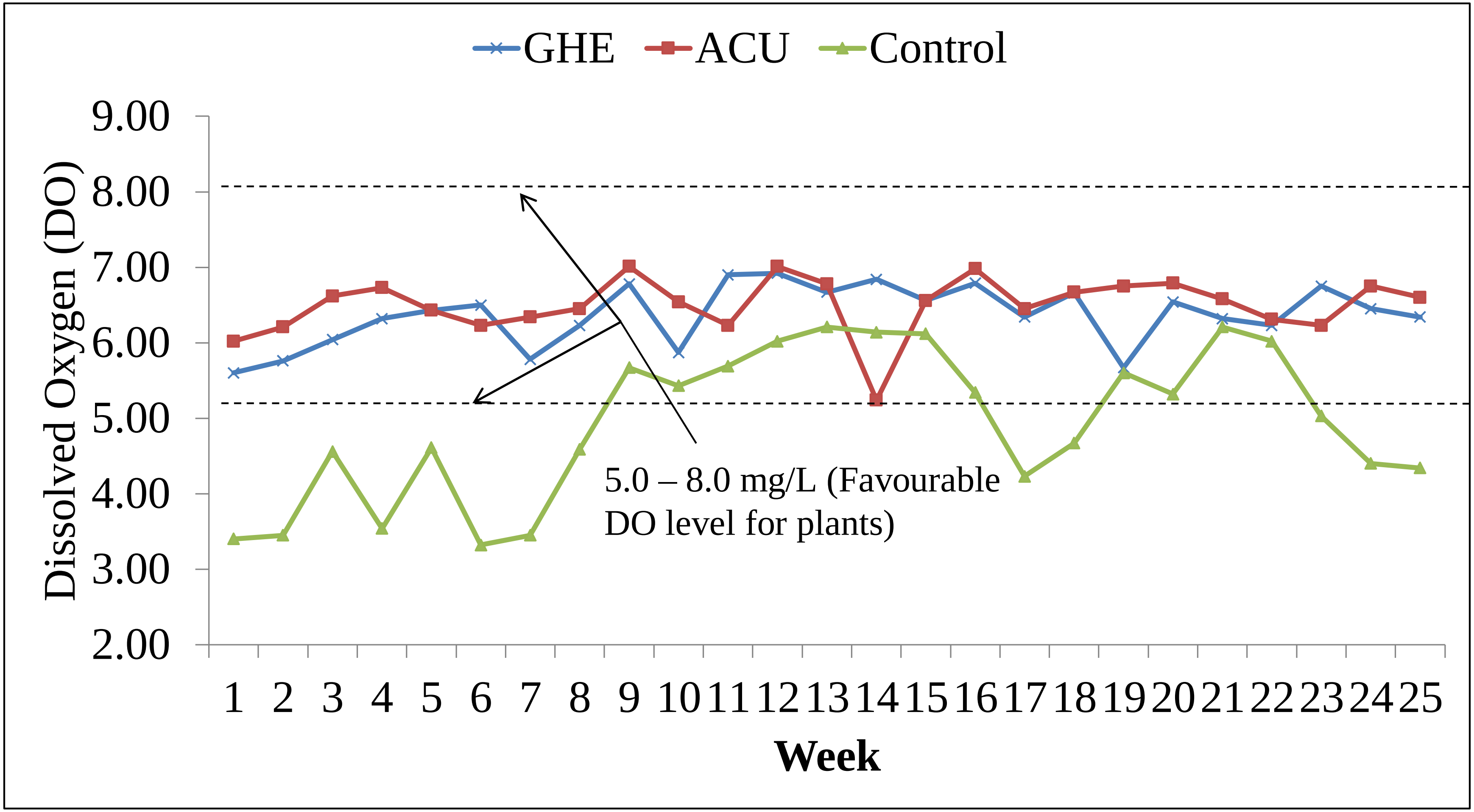
Average relative humidity inside the greenhouse at different times of the day



Average weekly pH of the nutrient solution at different plant maturity inside the greenhouse and in the open field



Average weekly EC of the nutrient solution at different plant maturity inside the greenhouse and in the open field



Average weekly DO of the nutrient solution at different plant maturity inside the greenhouse and in the open field

Yield (grams) of strawberry per plant with and without different root zone cooling methods and varying photoperiod.

ROOT ZONE COOLING METHOD	PHOTOPERIOD			MEAN
	8 hrs	16 hrs	Normal Day Length	
GHE w/o AIRCON	182.43	185.40	176.50	181.44a
GHE w/ AIRCON	194.07	189.11	176.09	186.42a
NO GHE	25.61	31.99	36.34	31.31b
MEAN	134.04a	135.50a	129.64a	

Means with the same letters are not significantly different based on LSD at 5% level.

Simple Cost Analysis

Cost and return analysis of aeroponically grown strawberry (72 sq. m. Greenhouse - 13 harvest times) in the lowland tropics.

FIXED COST	AMOUNT, PhP
Average interest on investment	18,000.00
Depreciation	18,000.00
Su- total	*36,000.00*
VARIABLE COST	
Seedling	15,000.00
Nutrient solution	7,000.00
Electricity	24,000.00
Chemicals	2,000.00
Labor	15,000.00
Repair and maintenance	5,000.00
Miscellaneous	5,000.00
Sub-total	58,000.00
TOTAL COST	109,000.00
GROSS INCOME	180,000.00
NET INCOME	71,000.00
AVERAGE PRODUCTION COST, Php/kg	181.67
BREAK-EVEN YIELD, kg	363.33

Six months potential production for aeroponically grown strawberry (13 harvest times) inside a greenhouse in the lowland tropics

POTENTIAL PRODUCTION	TOTAL
Number of vertical tower	100.00
Number of plants per tower	30.00
Total number of plants	3,000.00
Average yield per plant, grams	200.00
Total yield, kg	600.00
Cost per kg, PhP	300.00
POTENTIAL GROSS INCOME, PhP	180,000.00
TOTAL EXPENSES, PhP	109,000.00
POTENTIAL NET INCOME, PhP	71,000.00
NET INCOME PER SQUARE METER of GREENHOUSE, PhP	986.11
NET INCOME PER 1,000 SQ.M.	968,000.00

Simple Cost Analysis

Cost and return analysis of aeroponically-grown strawberry (72 sq. m. Greenhouse - 40 plants/tower and 26 times harvesting) in the lowland tropics

FIXED COST	AMOUNT, PhP
Average interest on investment	25,000.00
Depreciation	22,500.00
Su- total	*47,500.00*
VARIABLE COST	
Seedling	30,000.00
Nutrient solution	15,000.00
Electricity	35,000.00
Chemicals	5,000.00
Labor	20,000.00
Repair and maintenance	10,000.00
Miscellaneous	10,000.00
Sub-total	125,000.00
TOTAL COST	172,000.00
GROSS INCOME	432,000.00
NET INCOME	260,000.00
AVERAGE PRODUCTION COST, Php/kg	119.44
BREAK-EVEN YIELD, kg	573.33
NET PRESENT VALUE (10 years, 5% Inflation rate), PhP	2,007,651.08
BENEFIT COST RATIO (B/C)	8.03
RETURN ON INVESTMENT (10 YEARS), %	703.06
ANNUAL AVERAGE RETURN ON INVESTMENT, %	70.30

Six months potential production for aeroponically-grown strawberry (40 plants/tower and 26 times harvesting) inside a greenhouse in the lowland tropics

POTENTIAL PRODUCTION	TOTAL
Number of aeroponic tower	100.00
Number of plants per tower	40.00
Total number of plants	4,000.00
Average yield per plant, grams	360.00
Total yield, kg	1,440.00
Cost per kg, PhP	300.00
POTENTIAL GROSS INCOME, PhP	432,000.00
TOTAL EXPENSES, PhP	172,000.00
POTENTIAL NET INCOME, PhP	260,000.00
NET INCOME PER SQUARE METER of GREENHOUSE, PhP	3,611.11
NET INCOME PER 1,000 SQ.M.	3,611,111.11

Conclusion

- The use of ground heat exchanger for passive cooling is comparable with the use of air-condition for root zone cooling in terms of growth and yield of vertically and aeroponically grown strawberry plants .

- The application of ground heat exchanger for root zone cooling of aeroponically grown strawberry plant under tropical greenhouse condition has a very good production potential and is financially feasible.

Recommendation

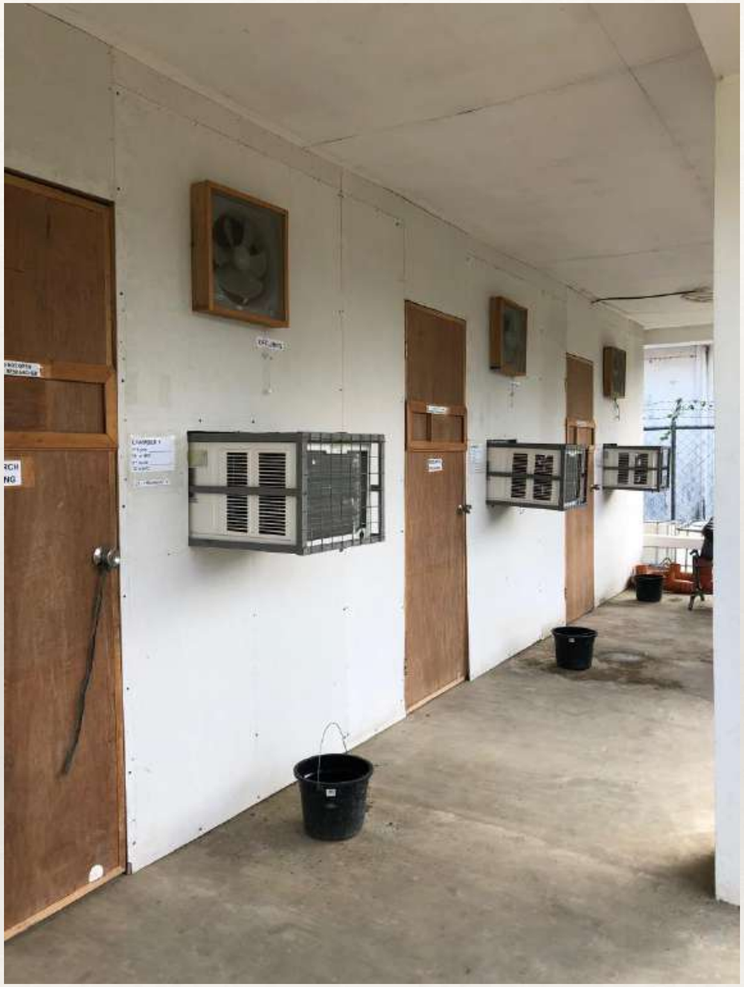
- Indoor application of using passive ground heat exchanger for roots and air cooling system instead of air-condition for all season production.
- The utilization of ground heat exchanger for root zone cooling of aeroponically grown crops under protected environment is highly recommended for adaption and mass production under Philippine condition and other countries with similar climate condition.


INDOOR PRODUCTION OF LOOSE-LEAF LETTUCE AT VARYING LIGHT
INTENSITIES AND PLANTING CHAMBER TEMPERATURES
(Semilla, 2018)

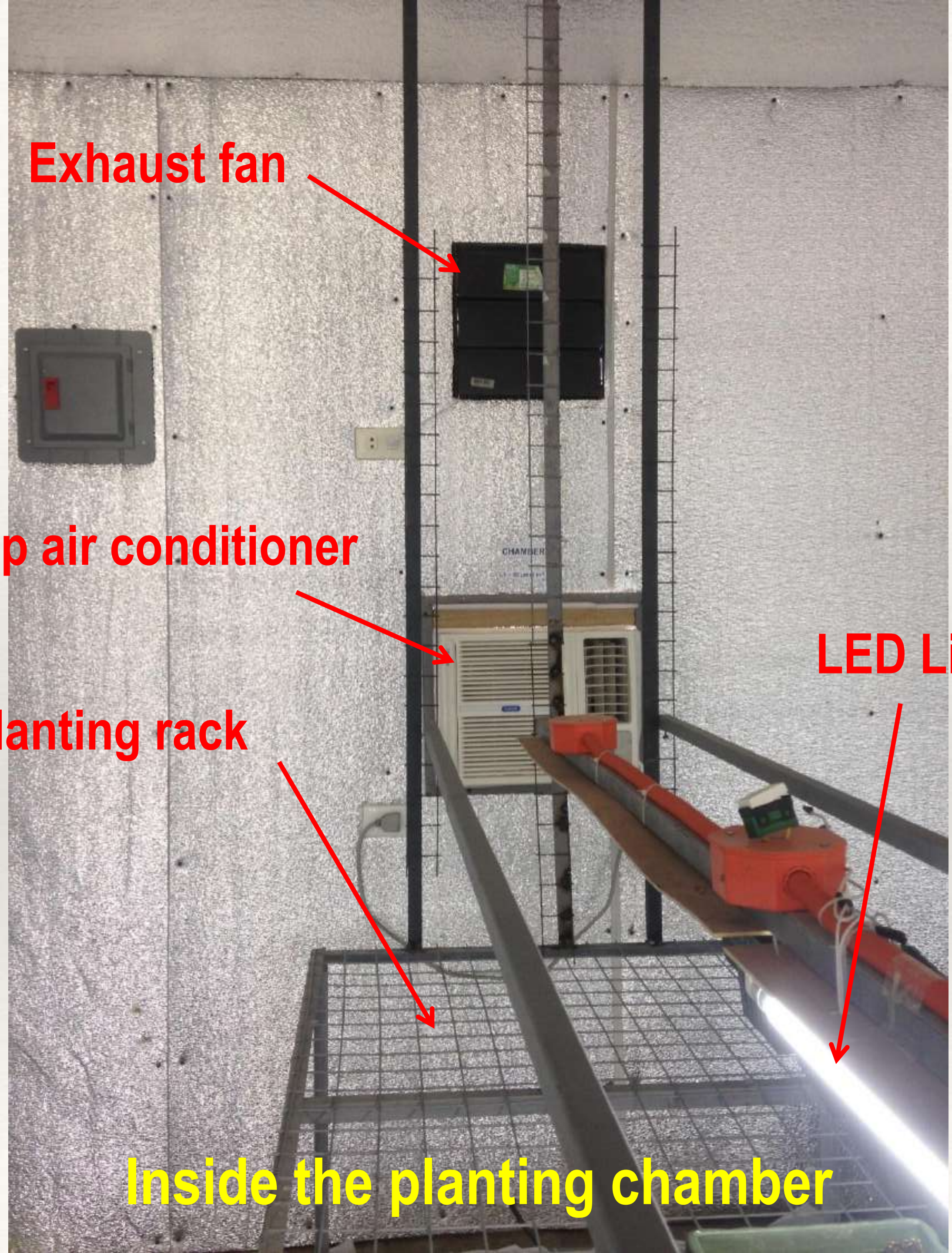
Prototype planting chambers that serve as indoor farm.
Land & Water Field Laboratory, College of Engineering, Central Luzon State University

Components:

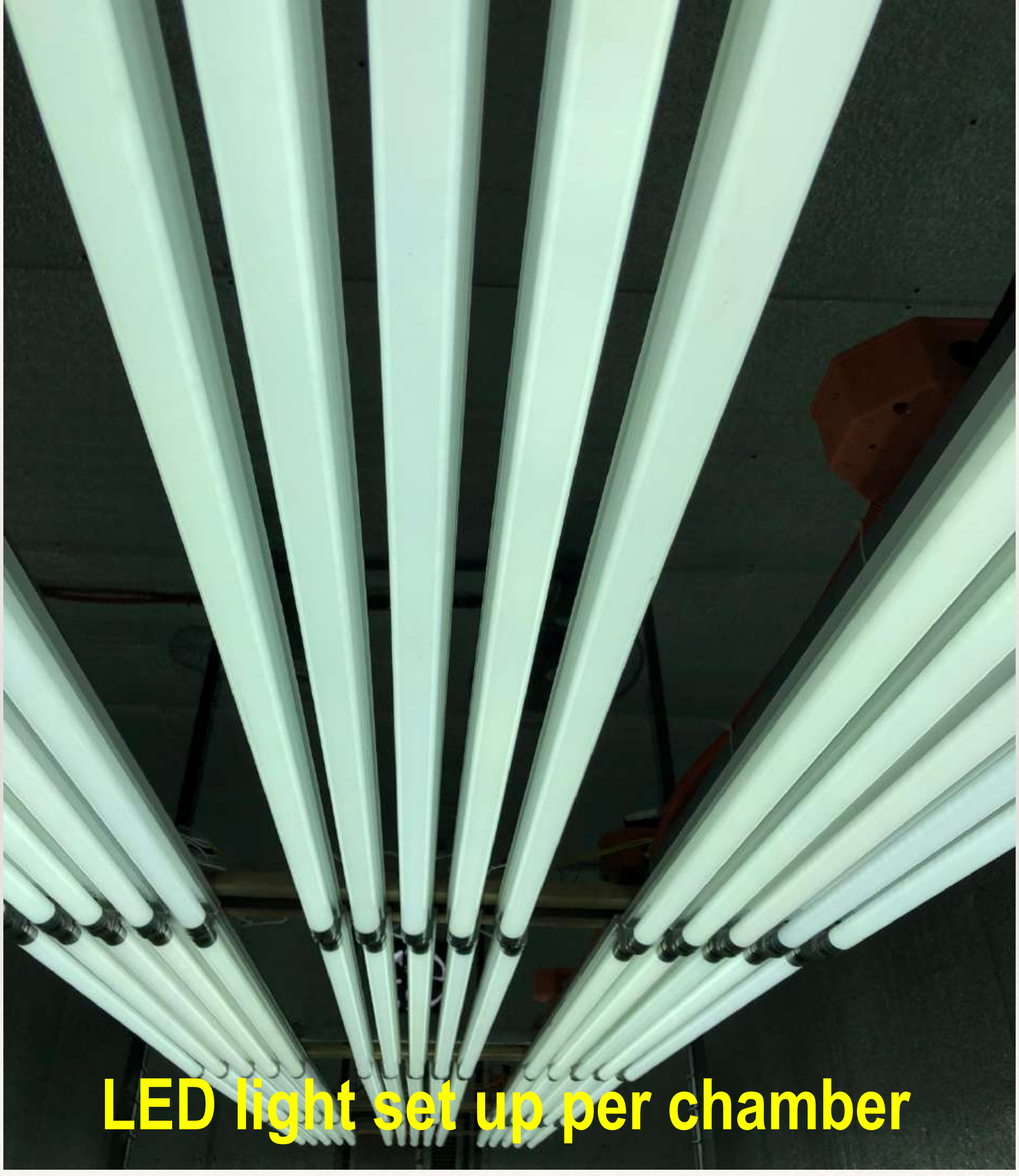
- 2 air conditioning units
- 2 exhaust fans
- 2 orbit fans
- sprinkler fogger
- Commercially available LED tube lights
- Chamber (2.5m x 6m x 2.7m)



Air conditioners and exhaust fans in front (left) and at the back (right) of the planting chambers.



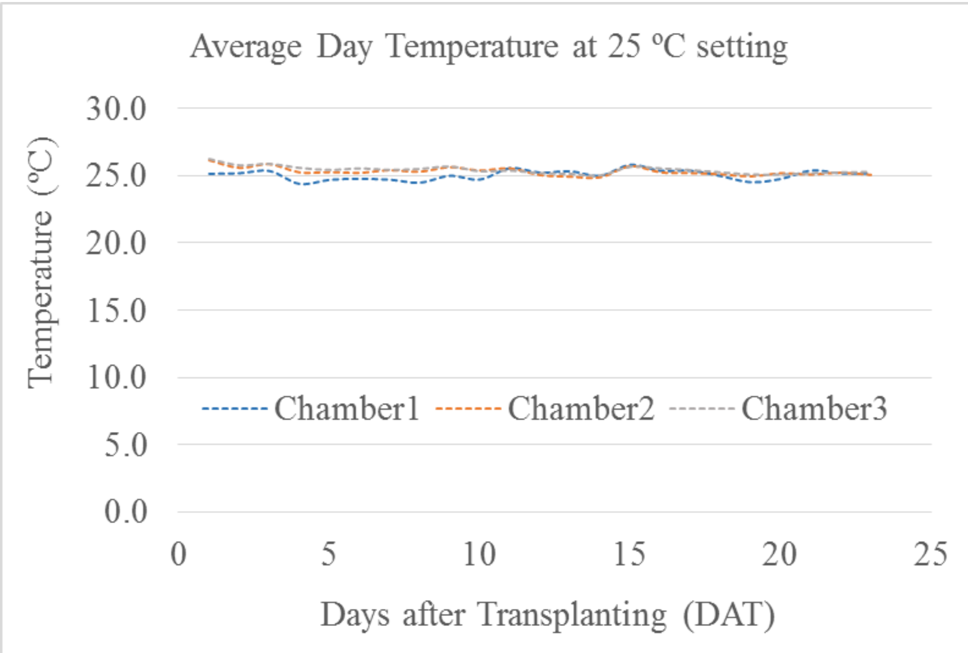
Inside the planting chamber

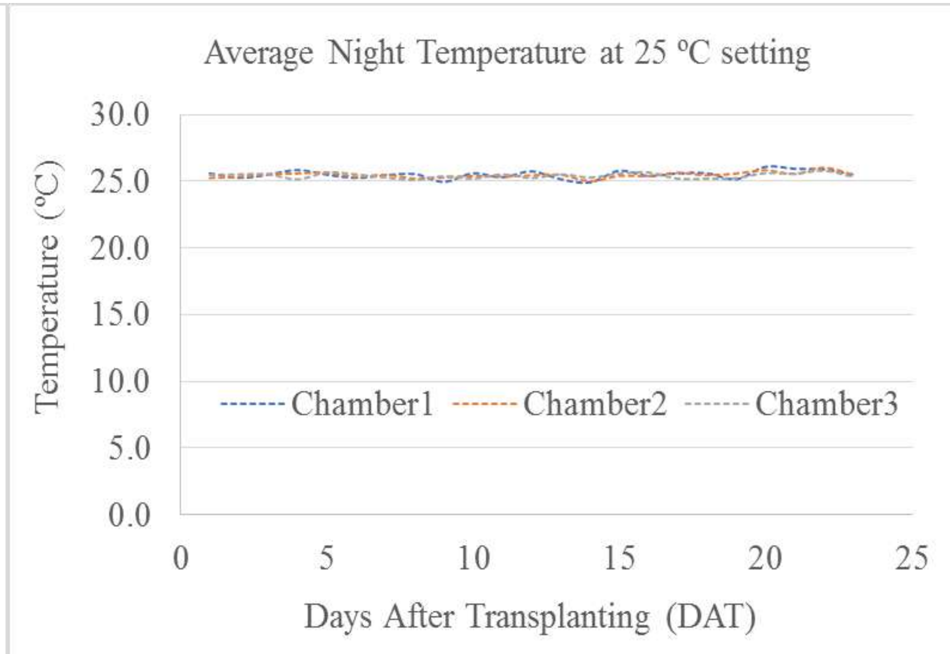

LED light set up per chamber

Circulating fans inside the planting chamber

Sprinkler fogger below the planting rack inside the chamber

Day and Night Temperature at 25 °C setting inside and outside the chmaber

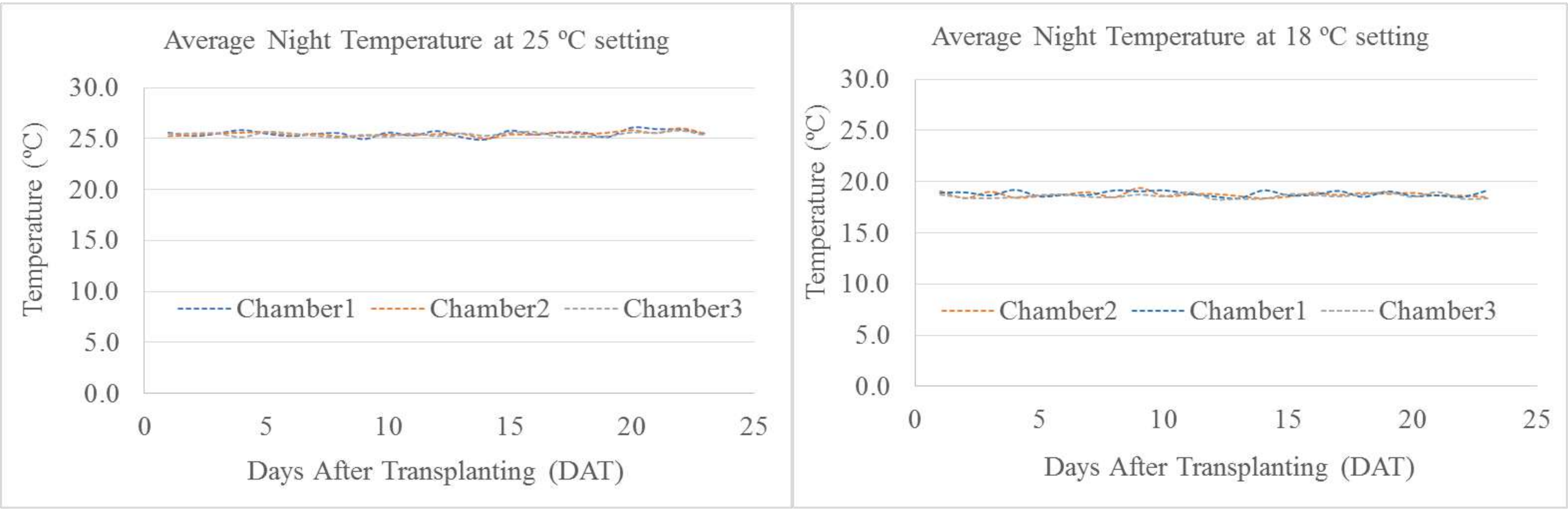




- Chambers: 25.3±0.4 °C and 25.5±0.2 °C
- Outside: 29.6±2 °C and 25.9±0.5 °C

(Semilla 2018)

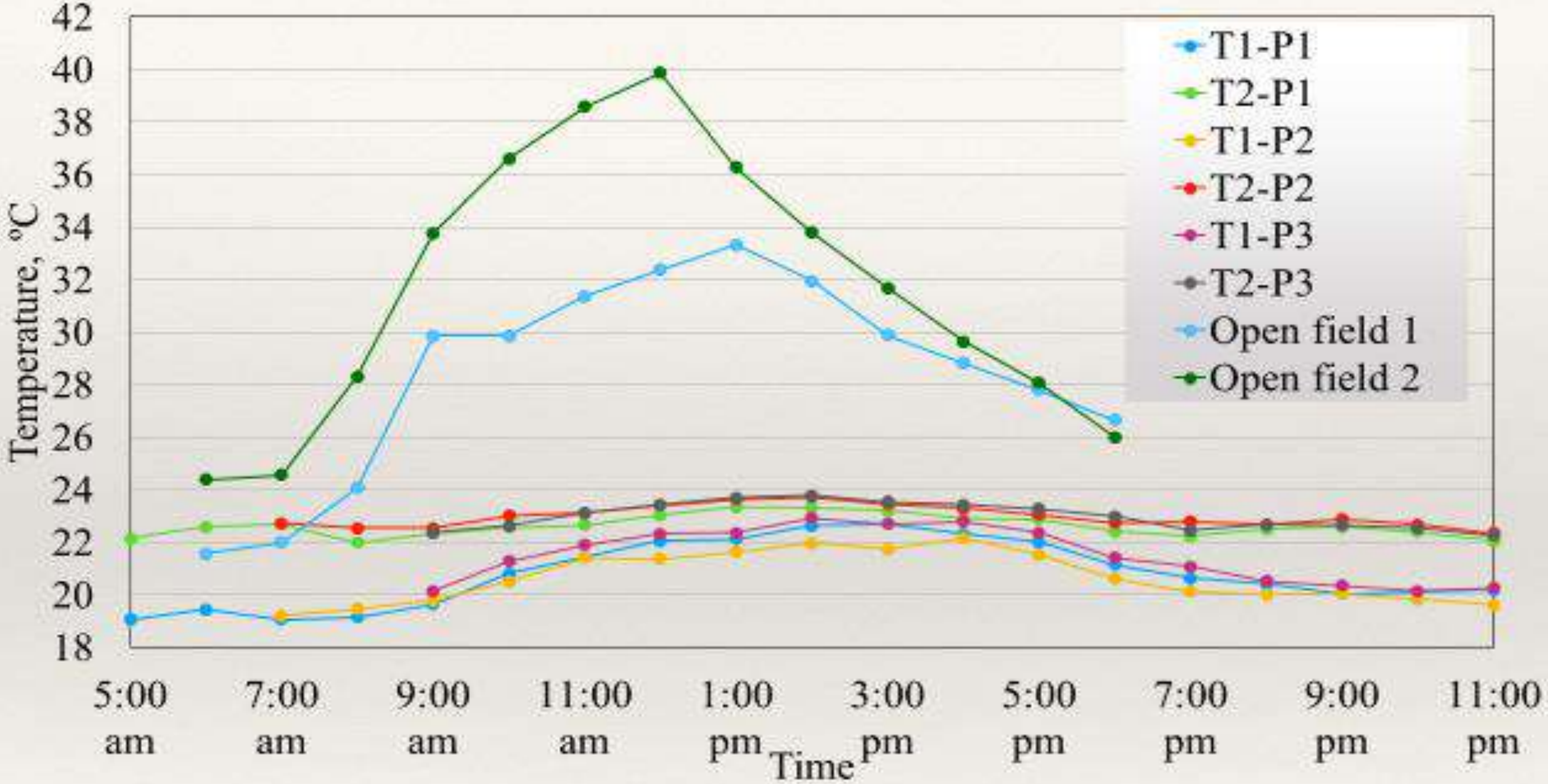
Day and Night Temperature at 18 °C setting inside and outside the chamber



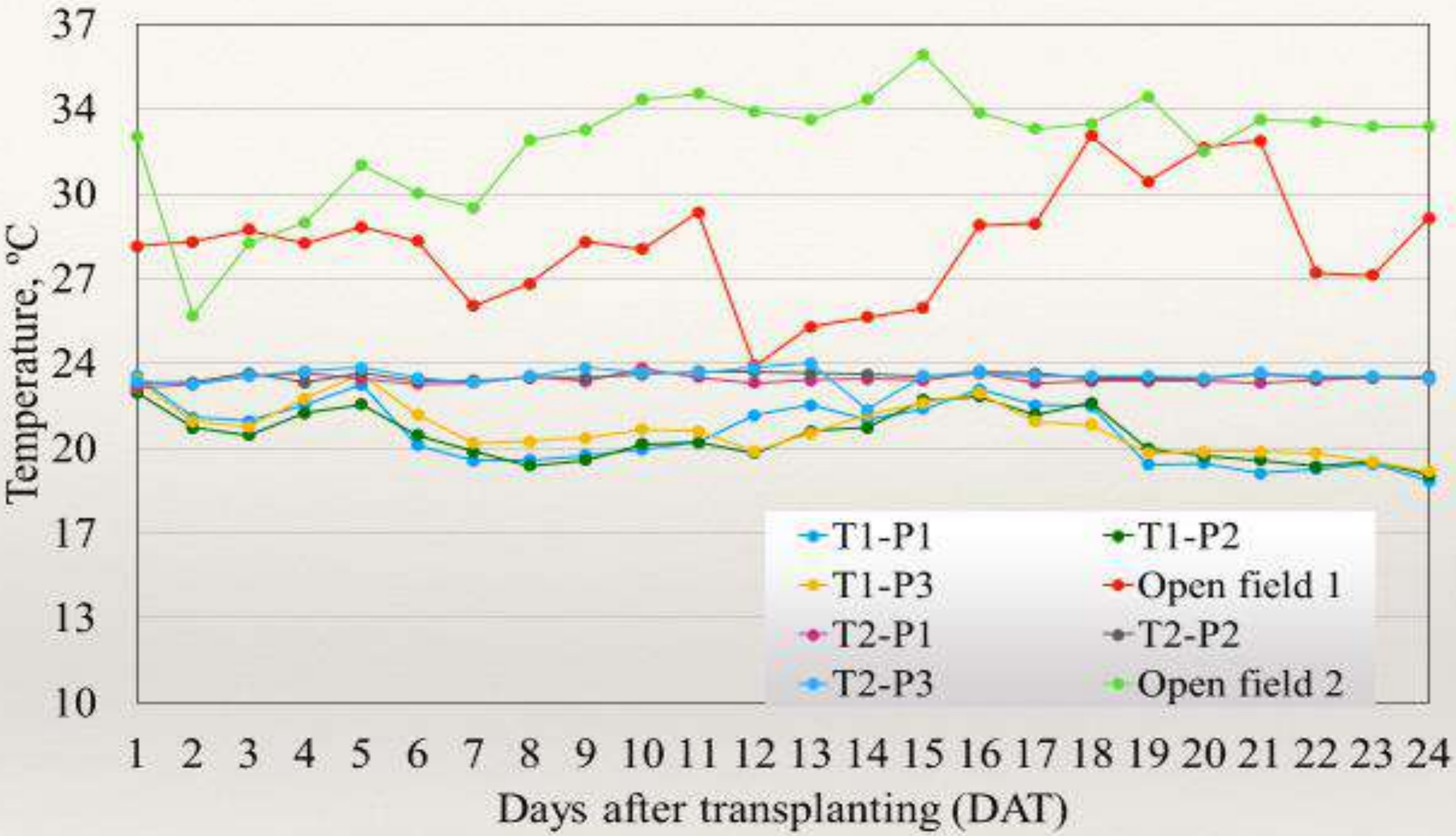
- Chambers: 18.9±0.6 °C and 18.7±0.3 °C
- Outside: 26.2±1 °C and 23.6±0.6 °C

(Semilla 2018)

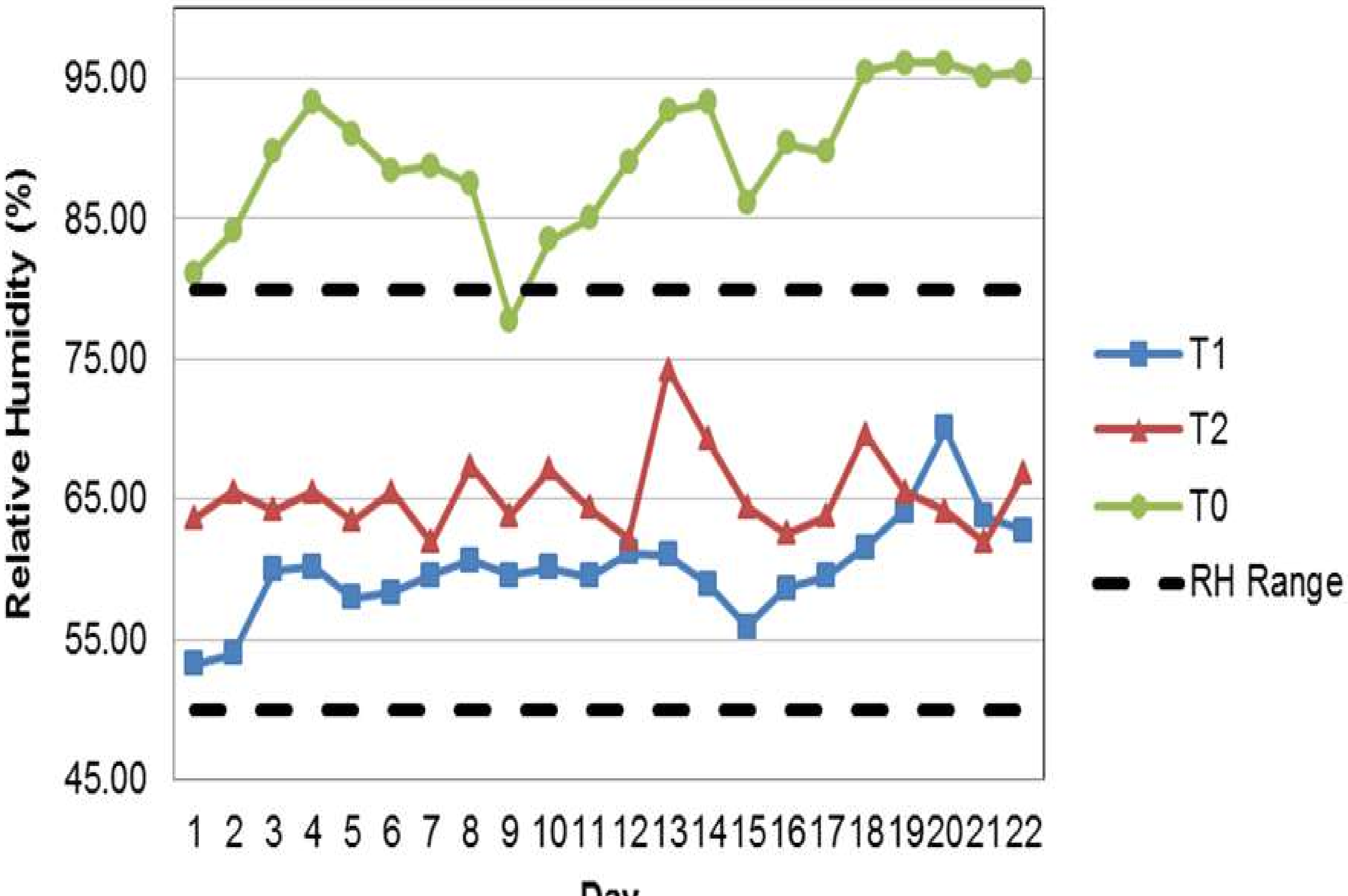
Temperature



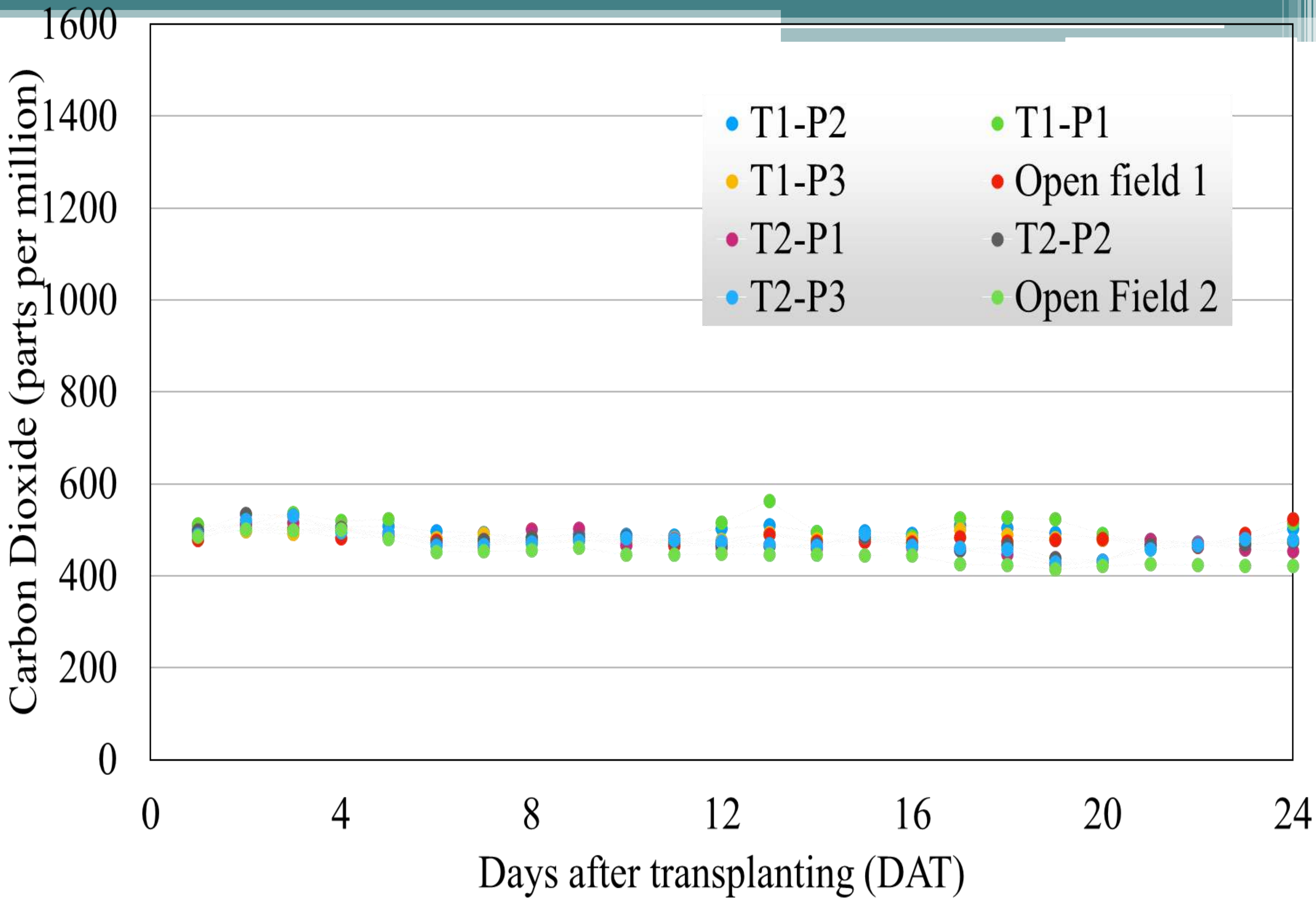
Average hourly temperature readings in first and second cycles inside three planting chambers and in the open field



Average daily temperature readings in the first and second cycles inside three planting chambers and in the open field



Average daily relative humidity inside (red and blue) and outside (yellow green) the chambers



Average daily CO_2 readings inside the chambers and in the open field

Light Intensity ($\mu mol\ m^{-2}\ s^{-1}$)	First Cycle, T_1 (25 °C)	Second Cycle, T_2 (18 °C)
50 (L_1)	102.38[c]	126.99[c]
100 (L_2)	284.92[b]	257.14[b]
150 (L_3)	400.79[a]	423.02[a]

- Outside: 316.67 grams per square meter

Yield ($g\ m^{-2}$) of Funfare lettuce inside the chambers at different light intensities

CONCLUSIONS

- CEA system can maintain the recommended temperature, relative humidity settings and CO2 for lettuce
- At least 150 PPF is highly recommended
- Quality of produced lettuce inside the chambers are better than those produced in the open field (lettuce in the open field tasted bitter)

Effect of Grow Room Temperatures on the Growth, Yield and Quality of Romaine Lettuce in an Indoor Farming System

(Fenangad, 2018)

Yield/plant of Romaine lettuce at different temperatures and light intensities inside the planting chambers and in the open field

Temp (°C)	Light Intensity µmol/m²– s)	Average Yield (g)
18	50	9.5[c]
	100	17.1[bc]
	150	22.6[abc]
25	50	5.8[c]
	100	19.9[abc]
	150	33.3[ab]*
Open Field		35.0*
*Bitter taste		

INDOOR FARMING TECHNOLOGY FOR GREEN ICE LETTUCE PRODUCTION USING DIFFERENT PHOTOPERIODS AND CHAMBER TEMPERATURES

(ARIOLA,2018)

Yield/plant (g) of green ice lettuce at 24 DAT as affected by chamber temperature (at 18 hours of photoperiod) as well as in the open field

TREATMENT	REPLICATION			TOTAL	MEAN
	1	2	3		
T1 - 20° C	55.00	53.67	54.33	163.00	54.33[b]
T2 - 23° C	65.33	80.17	83.33	228.83	76.28[a]
Open Field 1	54.83	53.67	52.67	161.17	53.72[b*]
Open Field 2	22.50	29.00	17.33	68.83	22.94[c*]

**Tasted bitter*

Note: Means with the same letter are not significantly different at 5% level

Conclusion

1. Temperature setting of 23° C with 18 hours of photoperiod gave the highest results in the production of green ice lettuce in terms of plant weight, plant height, leaf width, and number of leaves.

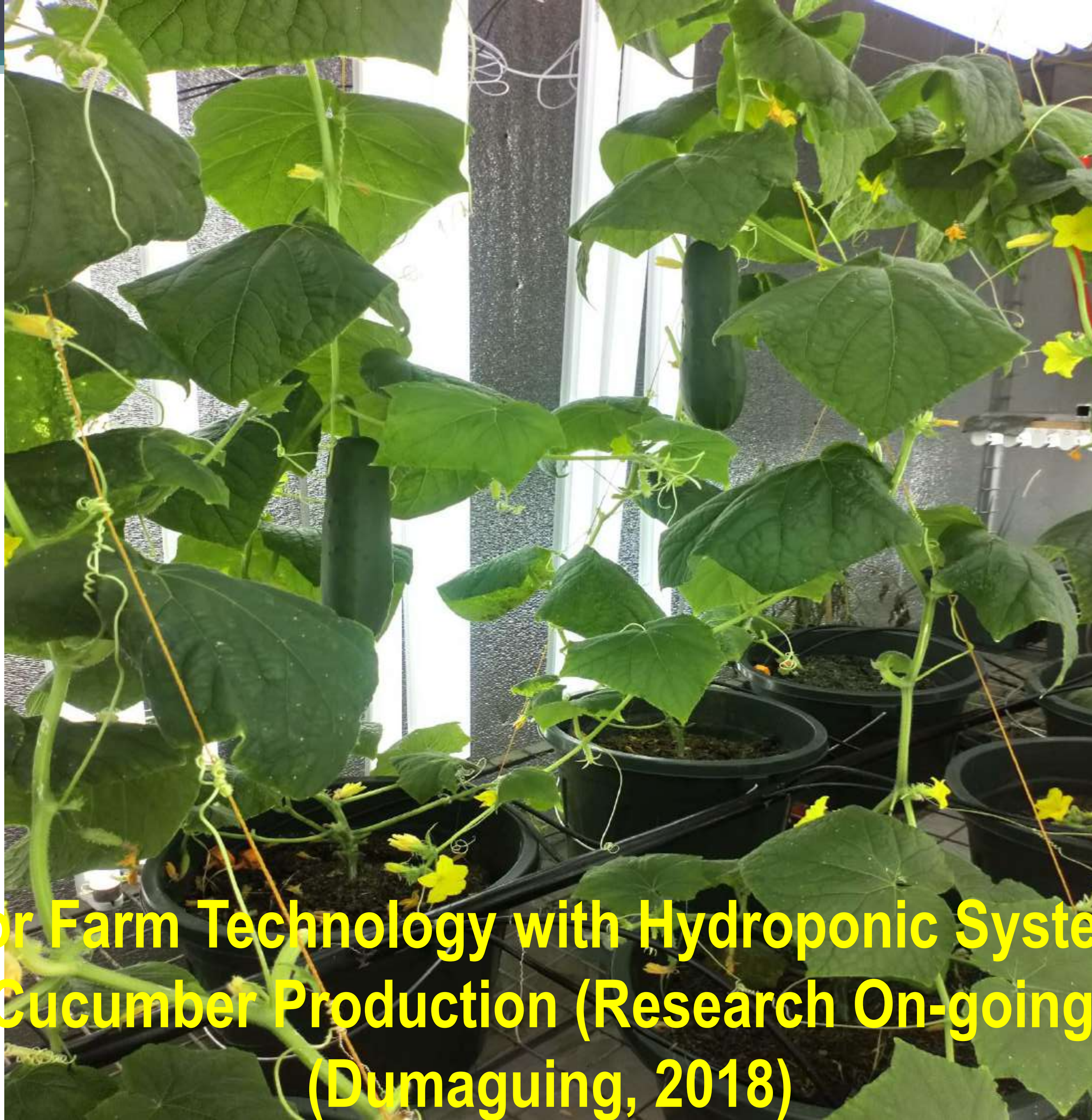
2. Growth and yield performance of green ice lettuce that is grown under different temperatures and photoperiods are significantly higher than the open field.

3. Sensory evaluation showed that green ice lettuce grown in the field caused a bitter taste compared to the green ice lettuce grown inside the chambers.

Recommendation

Temperature setting of 23° C and 18 hours of photoperiod is recommended since it gave the highest results in terms of green ice lettuce weight, height, leaf width, and number of leaves. It also produced leaves that are not bitter.

Indoor Farm Technology with Hydroponic System for Cucumber Production (Research On-going) (Dumaguing, 2018)



Indoor Farm Technology with Hydroponic System for Cucumber Production (Research On-going) (Dumaguing, 2018)


Tomato grown inside a chamber
(Research on-going)

Other Researches:

Project Title	Funding Agency	Remarks/Status	Proponent
Indoor Vertical Farming System (IVFS) for Whole Year Round Production of High Value Crops in the Lowland Tropics	CHED-PCARI	On-going	Agulto, Sace, Chuang and Auslander
Indoor Farm Technology with Hydroponic System for Cucumber Production in the Lowland Tropics	DOST-ERDT	On-going	Dumaguing, H.
Automated Greenhouse Environment for Vertically and Hydroponically Grown Red Leaf Lettuce with Rootzone Cooling Method in the Lowland Tropics	DOST-ERDT	On-going	Sulit, M.

Other Researches:

Project Title	Funding Agency	Remarks/Status	Proponent
Automated Romaine Lettuce Production Under Tropical Greenhouse Using Root Zone Cooling and Vertical Aeroponic Technologies	DOST-ERDT	On-going	Peneyra, M.
Indoor Production of Iceberg Lettuce at Different Photoperiods and Chamber Temperatures	DOST-ERDT	On-going	Ferrera, O.
Indoor Farm Technology for Cherry Tomato Production at Varying Temperatures and Photoperiods	DOST-ERDT	On-going	Gatchallian, S.

Other Researches:

Project Title	Funding Agency	Remarks/Status	Proponent
Indoor Farming System for Hydroponic Beefsteak Tomato Production	DOST-ERDT	For presentation and approval	Arroyo, J.
Indoor Production of Hydroponically Grown Arugula Under Micro-climatic Condition	DOST-ERDT	On-going	Vanguardia, R.
Automated Cherry Tomato Production Under Tropical Greenhouse Using Root Zone Cooling and Vertical Aeroponic Technology	DOST-ERDT	On-going	Pueyo, C.


THANK YOU…