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Technological and scientific issues related to precision agriculture

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Contents

- State of Indian agriculture (T Deshpande (2017))
- Precision and smart agriculture
- Current trends (Economist (2016), Nature (2017))
- Projects on agriculture at IISc
- Needs and issues

State of Indian agriculture

Tanvi Deshpande (2017) PRS Legislative Research (“PRS”).

- The agriculture sector employs nearly half of the workforces, contributes to 17.5% of the GDP .
- Over the past few decades, the manufacturing and services sectors have increasingly contributed to the growth of the economy, while the agriculture sector’s contribution has decreased from more than 50% of GDP in the 1950s
- India’s production of food grains has been increasing every year, and India is among the top producers of several crops such as wheat, rice, pulses, sugarcane and cotton. It is the highest producer of milk and second highest producer of fruits and vegetables. In 2013, India contributed 25% to the world’s pulses production, the highest for any one country, 22% to the rice production and 13% to the wheat production. It also accounted for about 25% of the total quantity of cotton produced, besides being the second highest exporter of cotton for the past several years.

Small holdings

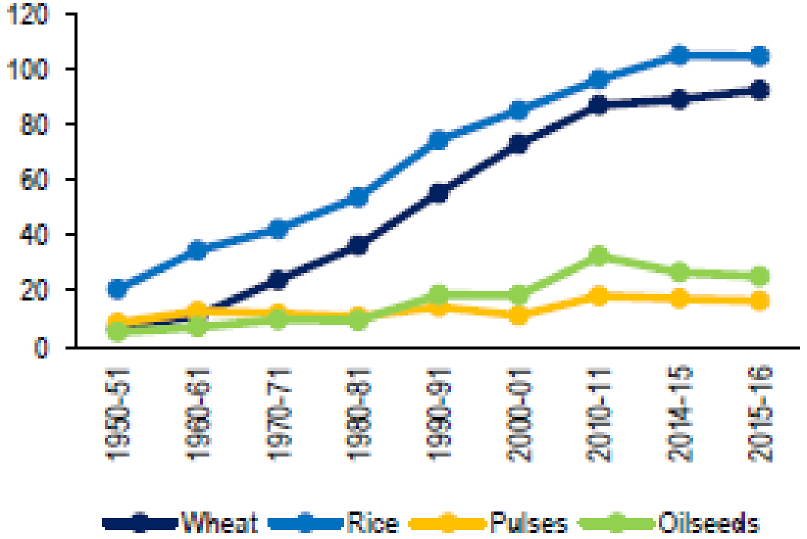
Table 3: Agricultural holdings (millions)

Holding	1970 -71	1980 -81	1990 -91	2000 -01	2010 -11
Marginal	36	50	63	75	93
Small	13	16	20	23	25
Medium	19	21	22	21	20
Large	3	2	2	1	1
All sizes	**71**	**89**	**107**	**120**	**138**

Note: Marginal: up to 1 hectare, Small: 1-2 hectares, Medium: 2-10 hectares, Large: over 10 hectares.
Sources: Agriculture Census 2011; PRS.

86% of land holdings are less than 2 hectares
Informal sources of credit constitute 40% of loans

Figure 5: Agricultural production (million tonnes)

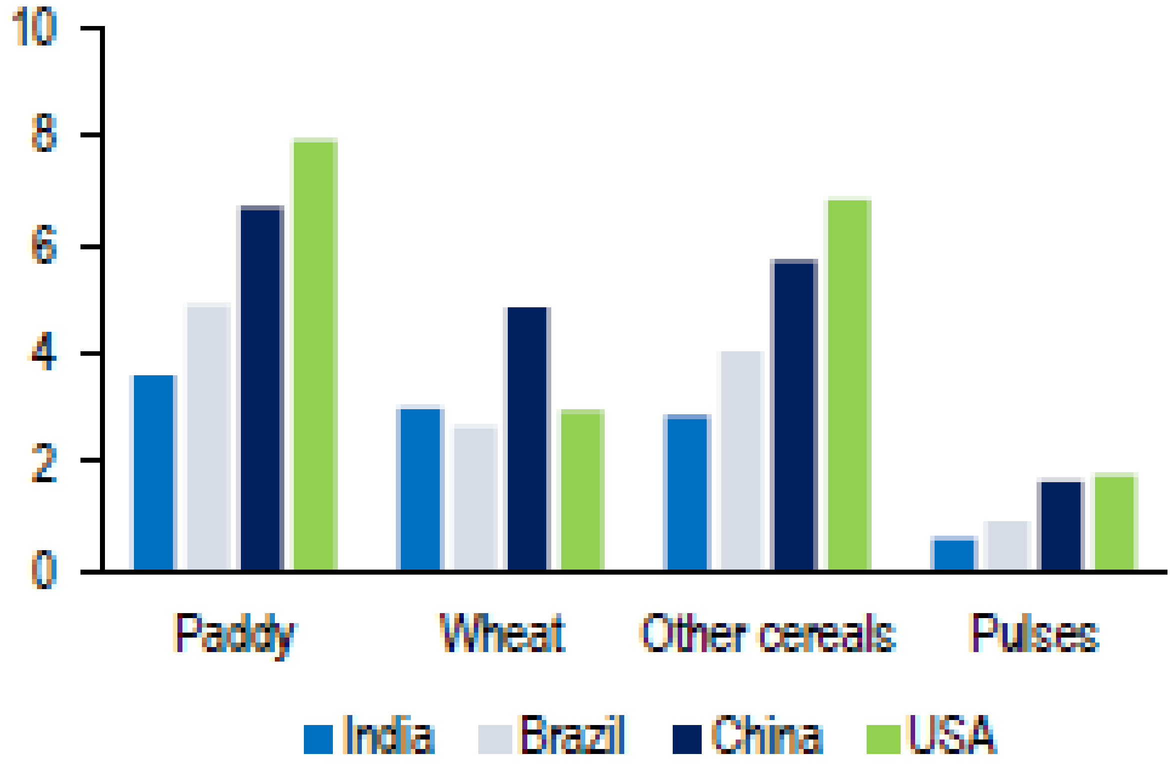


Total production of food grains increased from 51 million tonnes in 1950-51 to 252 million tonnes in 2015-16.

The production of wheat and rice took off after the green revolution in the 1960s, and as of 2015-16, wheat and rice accounted for 78% of the food grains production in the country.

Despite high levels of production in the country, 15% of the population continues to be under-nourished

Yield in different countries (tonne/ha)



Sources: Food and Agriculture Organization of the United Nations; PRS.

Problems

- Low farmer incomes; farmer debts
- Ground water depletion
- Deteriorating soil fertility
- Indiscriminate pesticide use

Precision/smart agriculture

- Yield-enhancing shifts in the past due to mechanisation, introduction of new crop varieties, agricultural chemicals (green revolution). Yields of rice, wheat plateauing.
- Precision agriculture: Giving ‘right’ amount of water, nutrients, pesticides at the ‘right’ times.
- How do we determine ‘right’?
- Drip/micro irrigation most common form.
- Increasingly sowing, watering, fertilising and harvesting are becoming computer-controlled.
- Sensing and feedback important: soil moisture, plant ‘status’ etc

- Airborne instruments can measure plant cover, distinguish between crops and weeds.
- Multispectral analysis, how strongly plants absorb or reflect different wavelengths of light, can plant health. eg estimate nitrogen needs spray right dose at a spatial point.
- Sensor (John Deere) spectroscopically measures nitrogen, phosphorous and potassium composition of liquid manure as it is being sprayed.
- Lot of data is produced that needs interpreting, requiring information technology.

Precision Farming Model for Peri-Urban agriculture

(funded by Bosch Centre,IISc)

Investigators:

(IISc) Jaywant H. Arakeri ,M.S.Bobji, R.N.Govardhan, R.V.Ravikrishna,

Usha Vijayaraghavan

(**JNCASR)** K.R. Sreenivas

(UAS, Bangalore) M. Udayakumar, S. Bhaskar

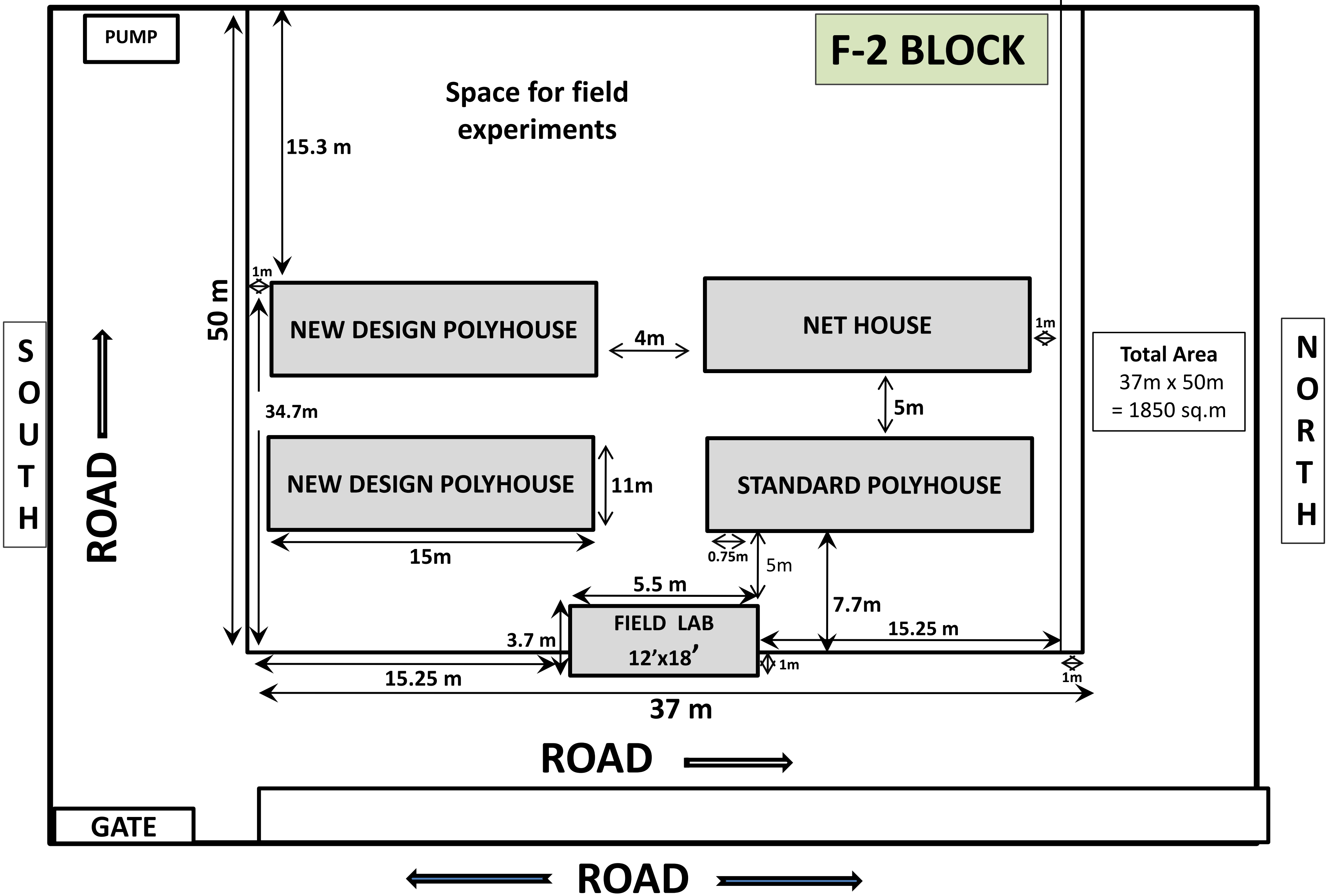
Main goals of the project

1. To design a polyhouse suitable for Indian climatic conditions

2. To develop systems to enhance input use efficiency of water and nutrients.

3 To conduct experiments with different crops in the polyhouse

EXPERIMENTS AT UAS



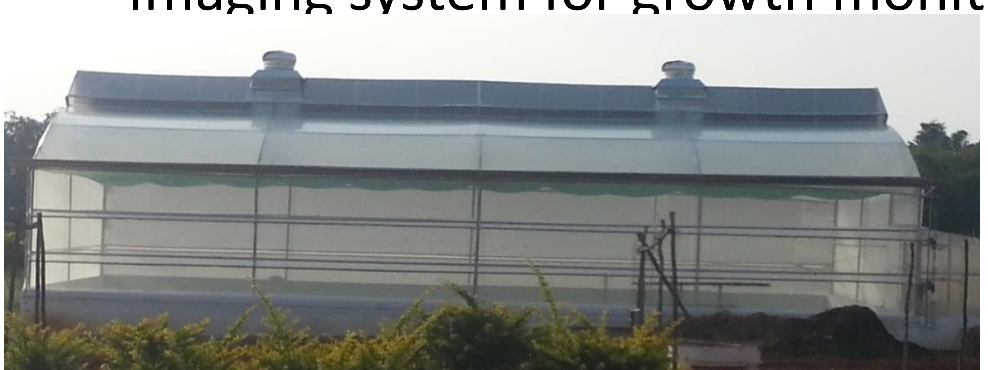
GREEN OR POLYHOUSE HOUSE

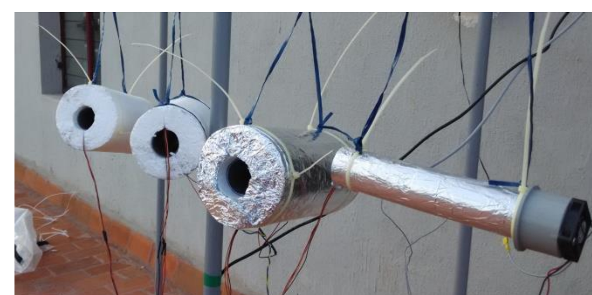
- Greenhouse cultivation also known as protected cultivation – keeps diseases, insects out.
- Temperature control: ventilated polyhouse, fan-pad system
- Temperatures within polyhouse higher than ambient – many times not desirable in India.
- Suitable for certain crops – flowers, tomato, capsicum

Polyhouses –Devanahalli

New Technologies Developed

- New polyhouse design – much lower temperatures than in traditional ones.
- Mini-lysimeter – monitoring evapo-transpiration losses
- Programmable fertigation – new type of precision irrigation
- Leaf mimic – to measure local evaporation rates as in a leaf.
- Forced ventilated temperatures sensors – to prevent radiation from affecting temp measurment in windless environments.
- Imaging system for growth monitoring





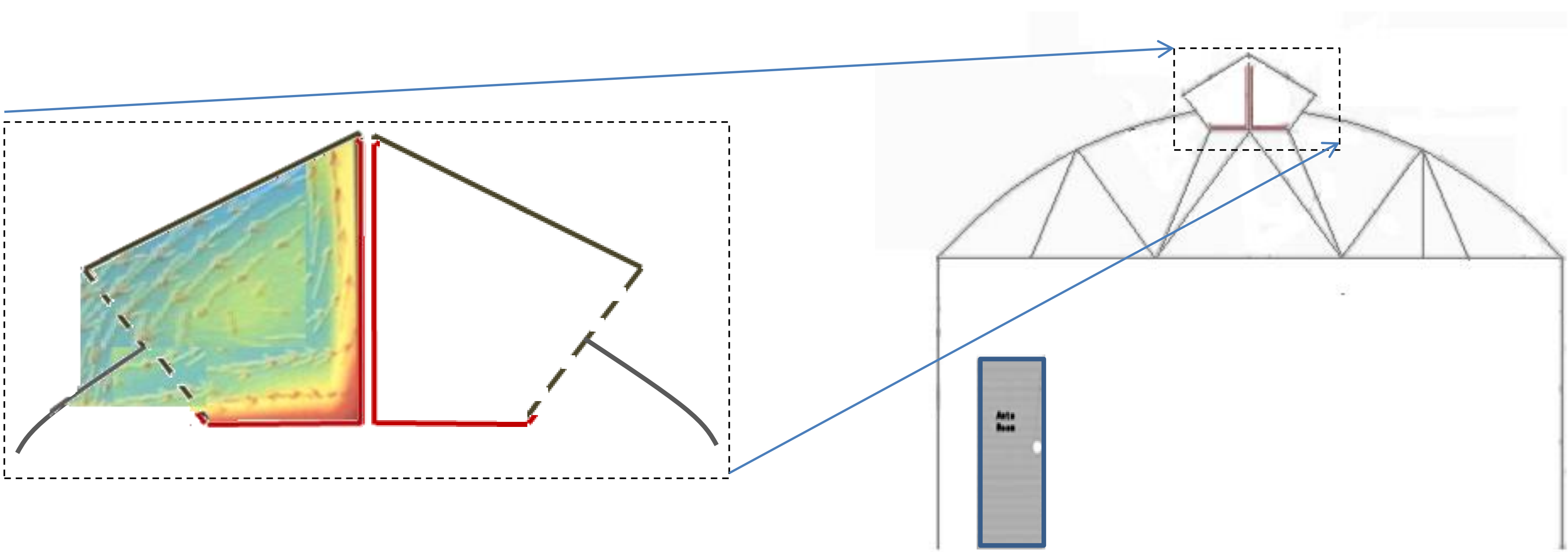
New polyhouse

Most designs from Israel

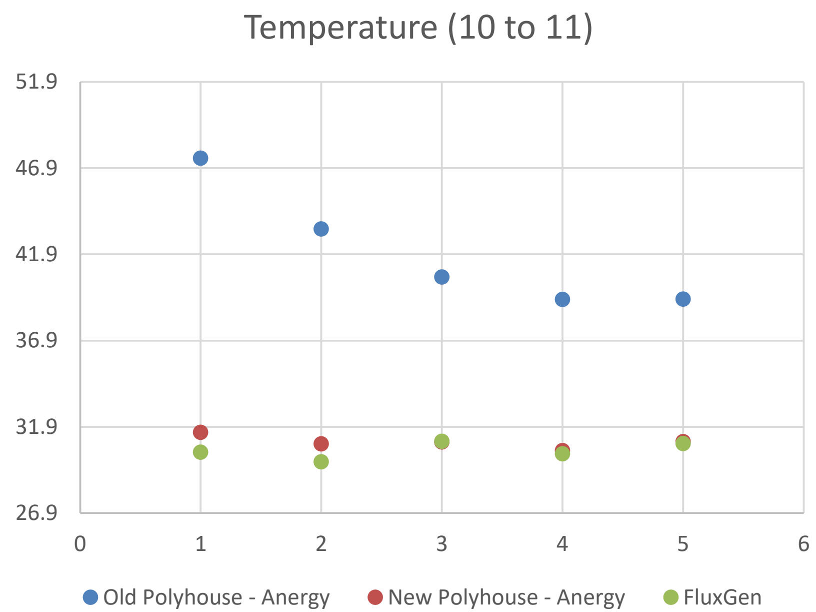
Use chimney: ventilation rate most when sun most intense, reduce effect of wind on ventilation

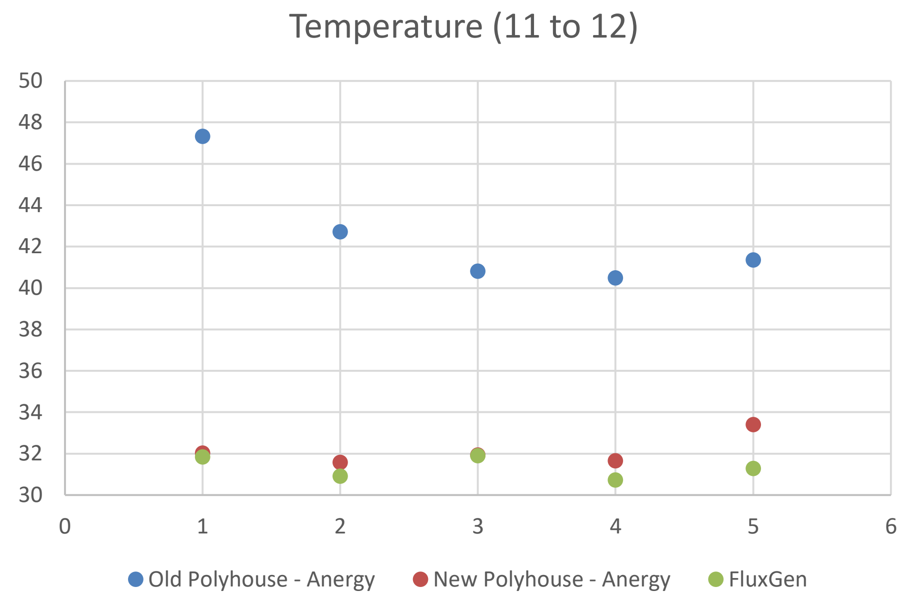
Polyhouse with solar-chimney

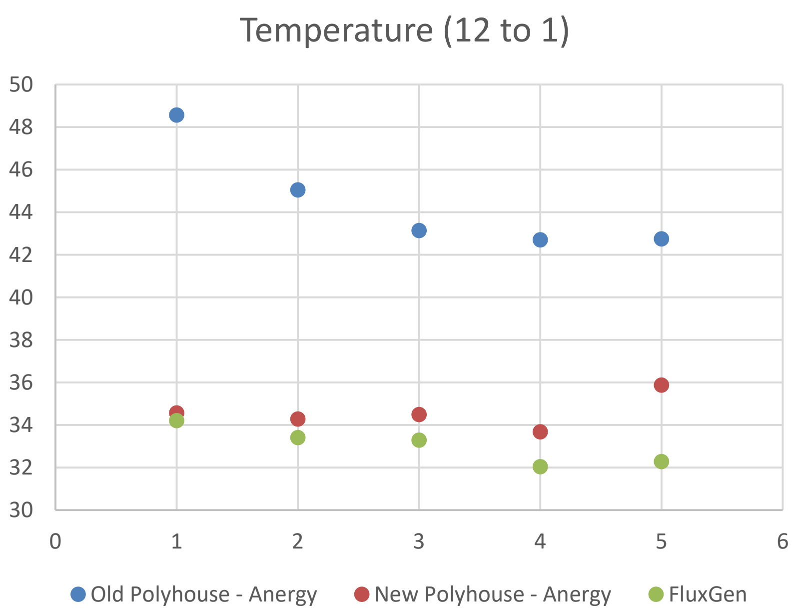
- runs along polyhouse
- vertical barrier absorbs radiation, reduces wind effect

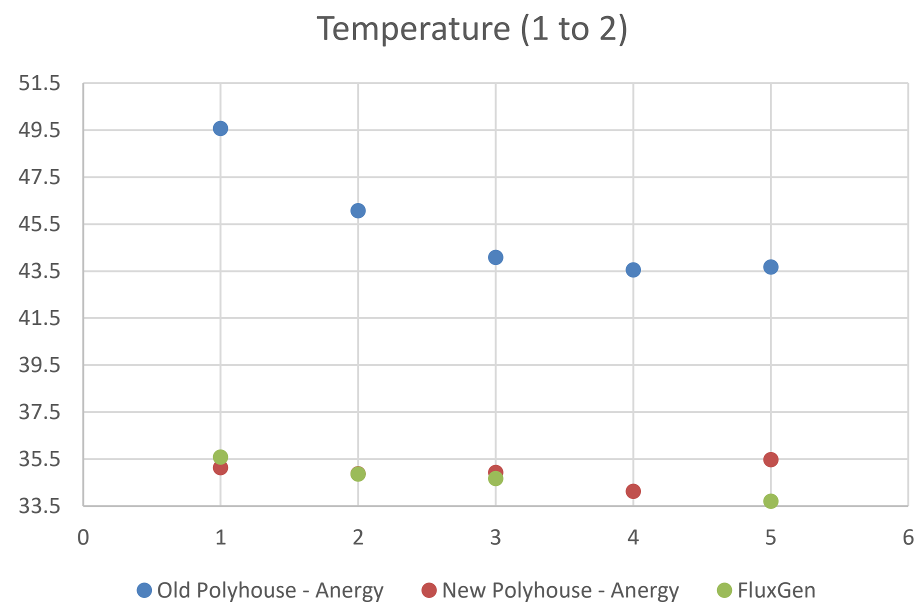


Temperature Distribution : Standard Vs New polyhouse



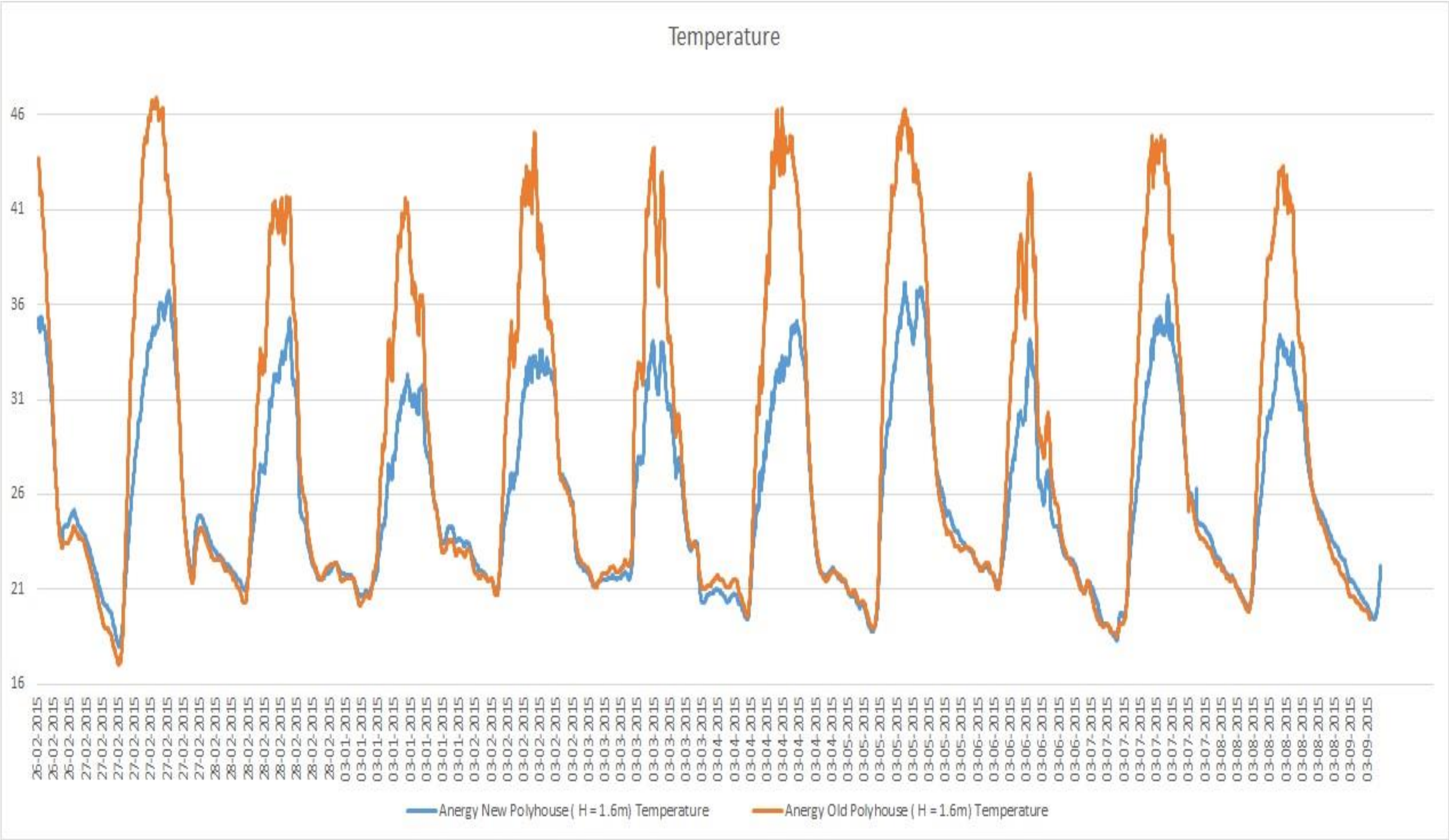






COMPARISON - OLD POLYHOUSE & NEW POLYHOUSE - ANERGY

26/02 – 09/03



Water

Water needs

- about 51% of the agricultural area cultivating food grains is covered by irrigation; rest of the area is rain-fed agriculture. Sources of irrigation : ground water (wells, tube-wells) and surface water (canals, tanks).
- Irrigation currently consumes about 84% of the total available water in the country; 65% of the irrigated land holdings use ground water sources and is fast depleting .
- India uses 2-3 times as much water to produce one tonne of grain as countries such as China, Brazil and the United States

Plants loose huge amounts of water

- > 90% water taken by roots released into air
- Sunflower: kg for kg intakes and eliminates 17 times more water than humans
- 1kg of rice needs ~ 4000 L of water; ragi needs 1000 L
- Water lost through stomata which occupy only ~ 1% of leaf area. But water lost can be as much as 50% from an open water body. ~ 5 mm/day; 1500 mm/year
- How much water loss is really required ?
- What factors control water loss? How is yield related to water intake?
- Need to answer these questions for precision agriculture.

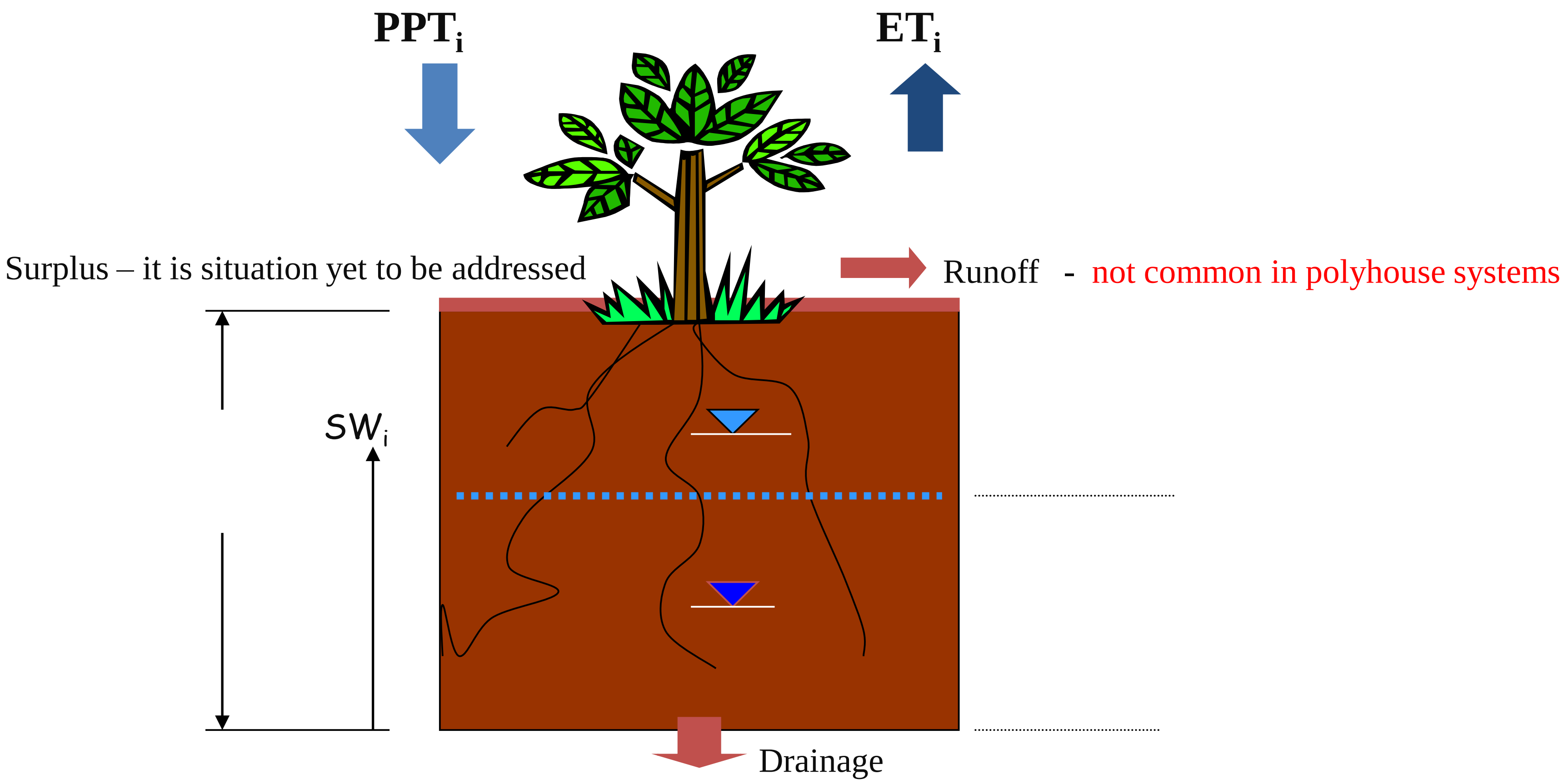
Issues

- Transpiration related in complicated ways to light, air and leaf temperatures, humidity, air flow and turbulence.
- Difficulties associated with flow physics at both leaf and canopy levels
- Stomata opening additional complication – temperature, carbon dioxide, humidity, water stress all affect opening

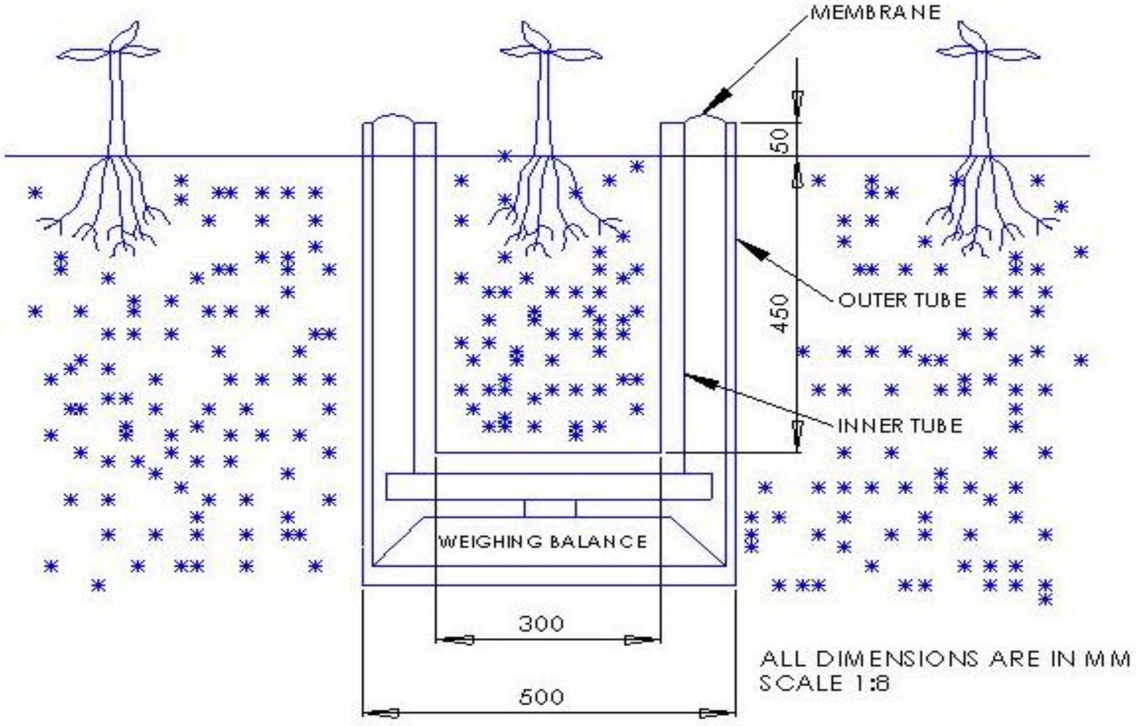
Approximate values of seasonal crop water needs

Crop	Water requirement (mm)
Rice	900-2500
Wheat	450-650
Sorghum	450-650
Maize	500-800
Sugarcane	1500-2500
Groundnut	500-700
Cotton	700-1300
Soybean	450-700
Tobacco	400-600
Tomato	600-800
Potato	500-700
Onion	350-550
Chillies	500
Sunflower	350-500
Castor	500
Bean	300-500
Cabbage	380-500
Pea	350-500
Banana	1200-2200
Citrus	900-1200
Pineapple	700-1000
Gingelly	350-400
Ragi	400-450
Grape	500-1200

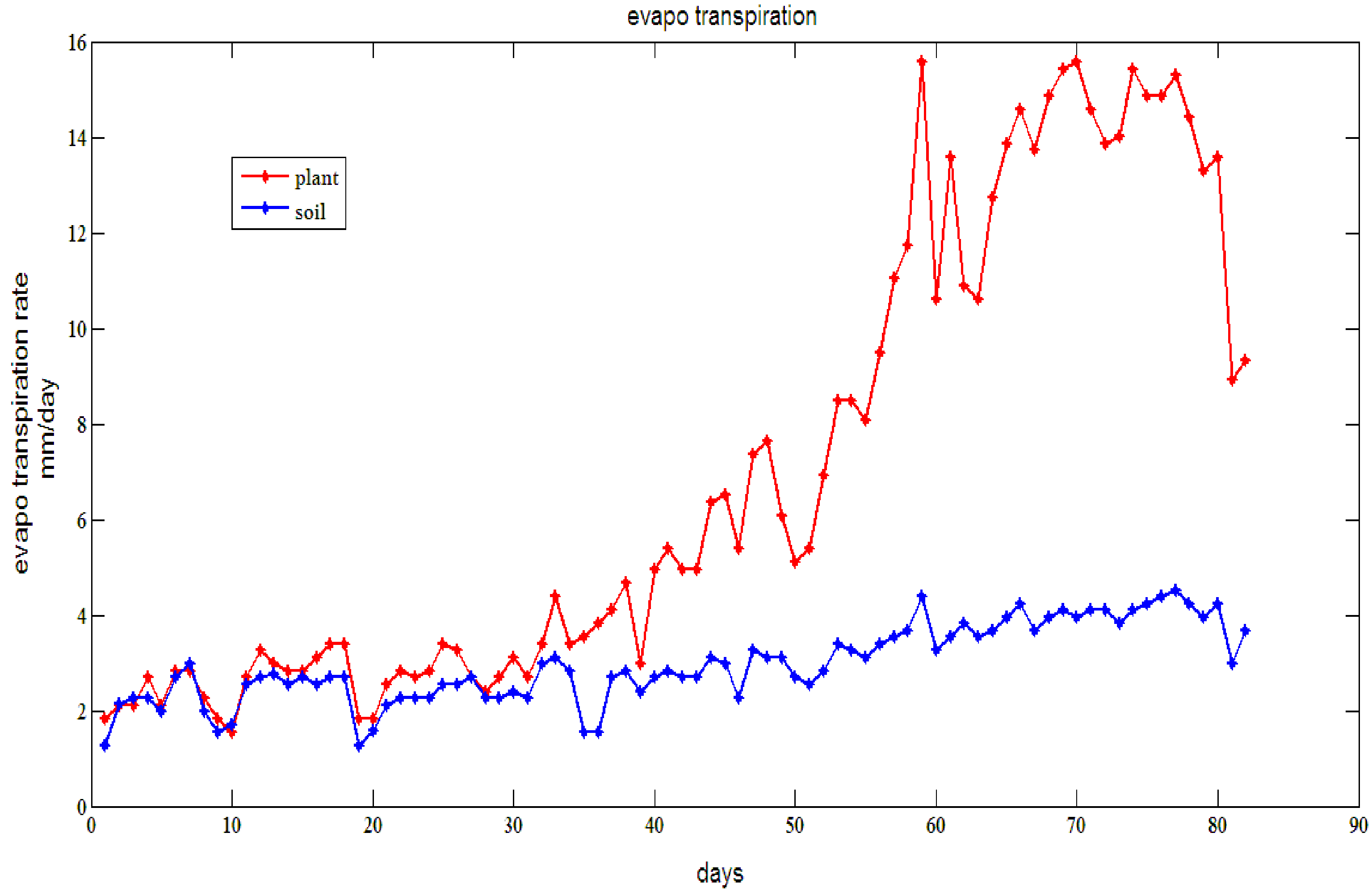
Scheme for crop water balance analysis – Mini lysimeter studies



Crop water balance studies– Mini lysimeter



Mini lysimeters in replicates will be established to collect the water balance data – evapotranspiration (diurnal variability) over a life cycle of the crop



evapo transpiration
evapo transpiration rate
mm/day
days
plant
soil
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
80
90

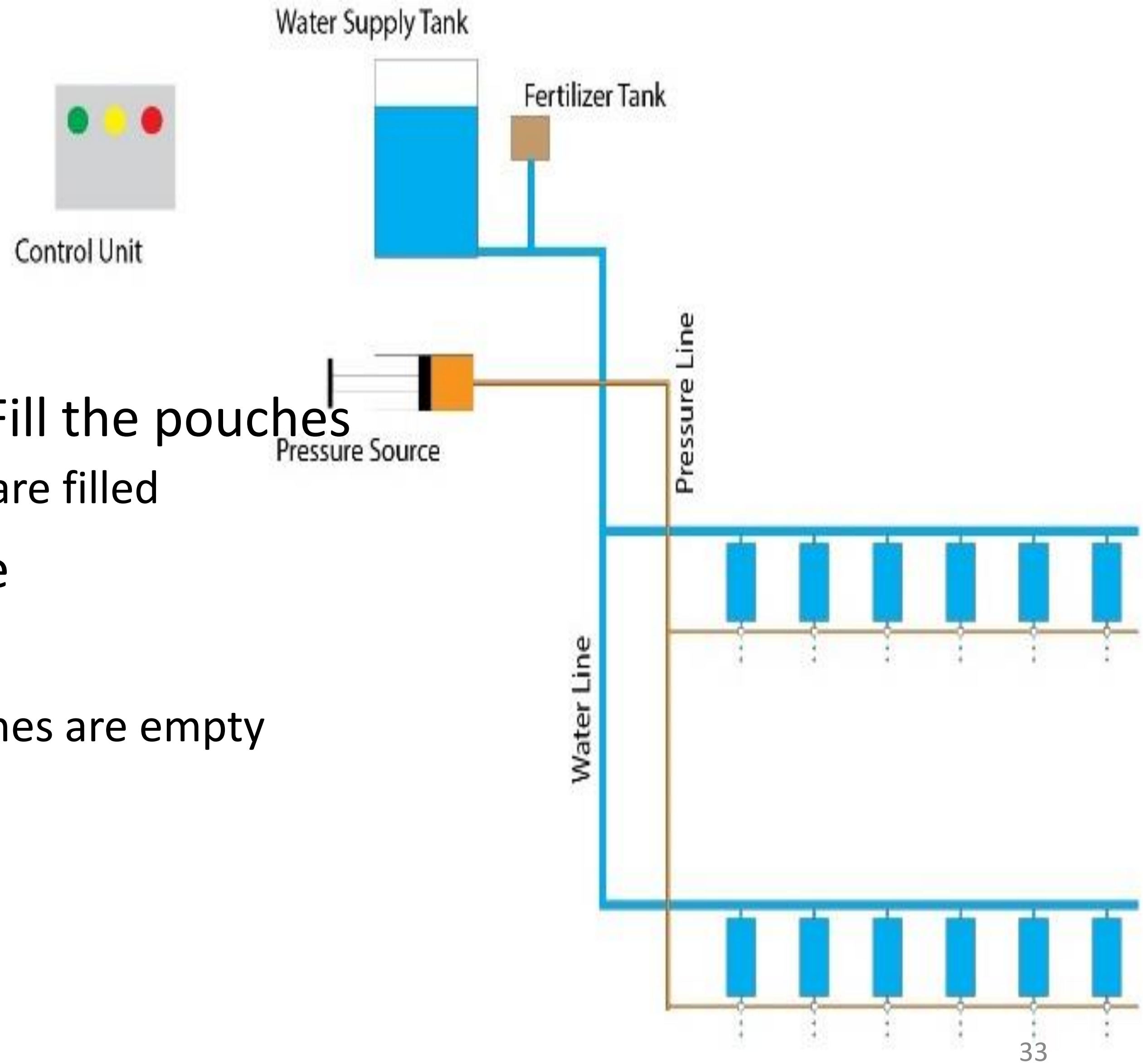
Drip Irrigation

- Controlled amounts of water (~4 L/h) to root zone
- High pressure required
- Problems with clogging

Emitters

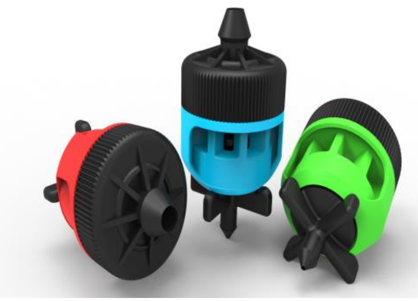
Many shapes and styles
- complex fluid mechanical design
-High pressure required ~ 1 bar
-Micro- circuitous channels

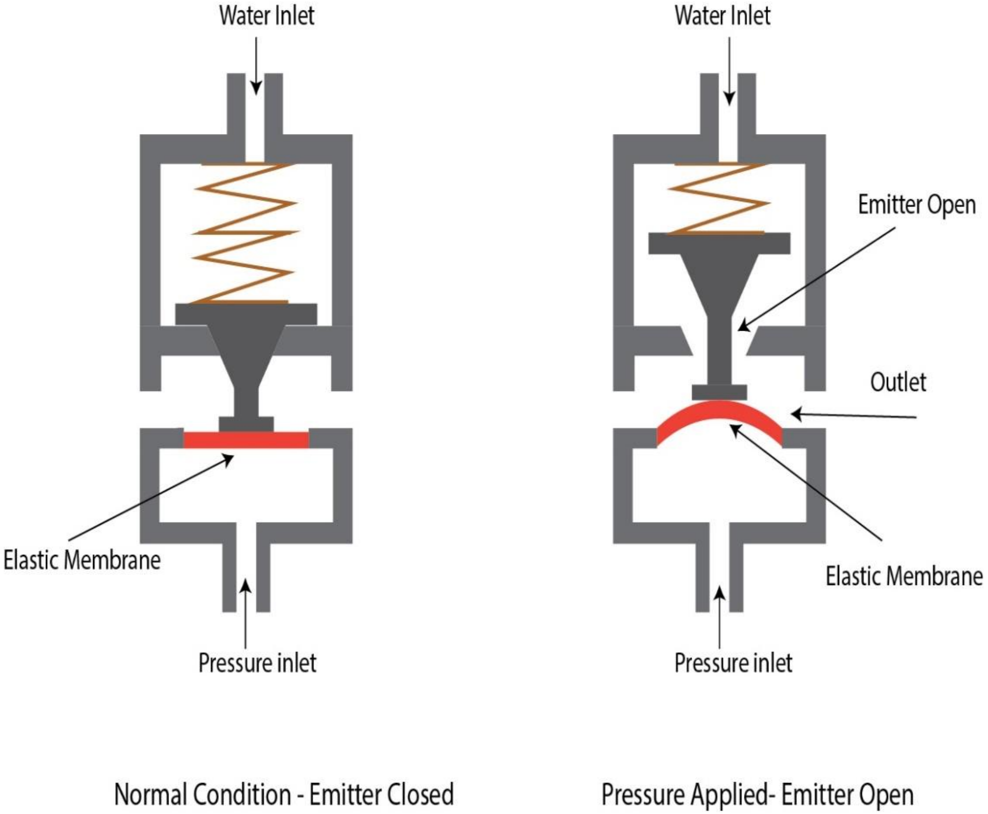
New intermittent type irrigation system



- Open supply line & Fill the pouches
  - Wait until pouches are filled
- Close the Supply line
- Open the emitter
  - Wait until the pouches are empty
- Close the emitter
- Repeat

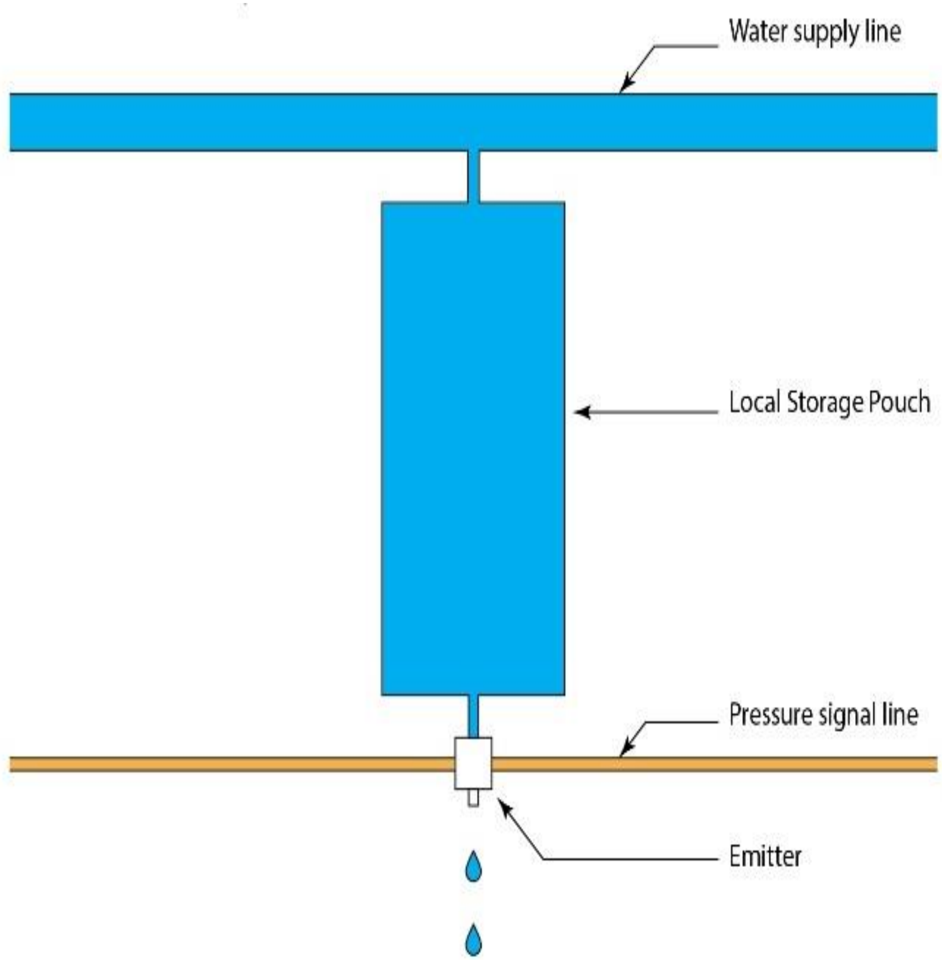
Emitter - Working





Working process of the emitter

Emitter - Pouch Assembly



Advantages

- Large opening – 1.5mm (can be further increased)
  - No chance for clogging
- Very low pressure head requirement
  - No need of pumping
- Controllable at emitter level
  - More accurate supply of water and fertilizer
- Intermittent Supply of water
  - Irrigation throughout the day
  - Required for plants

New trends

- Sensor networks
- Imaging – visual, hyper-spectral, IR
- Drones
- Hydroponics, aeroponics
- LED lighting

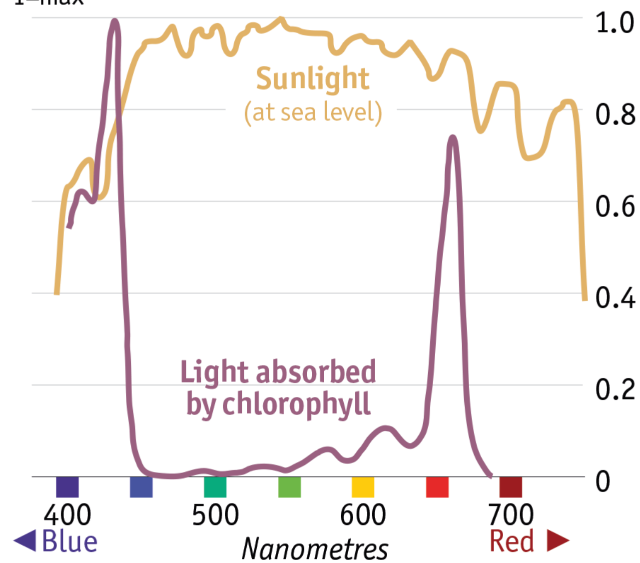
Economist (2016)

Use only light required by plants. LEDs with right wavlengths makes growing plants without sunlight possible

Wasted illumination

Emission/absorption by wavelength

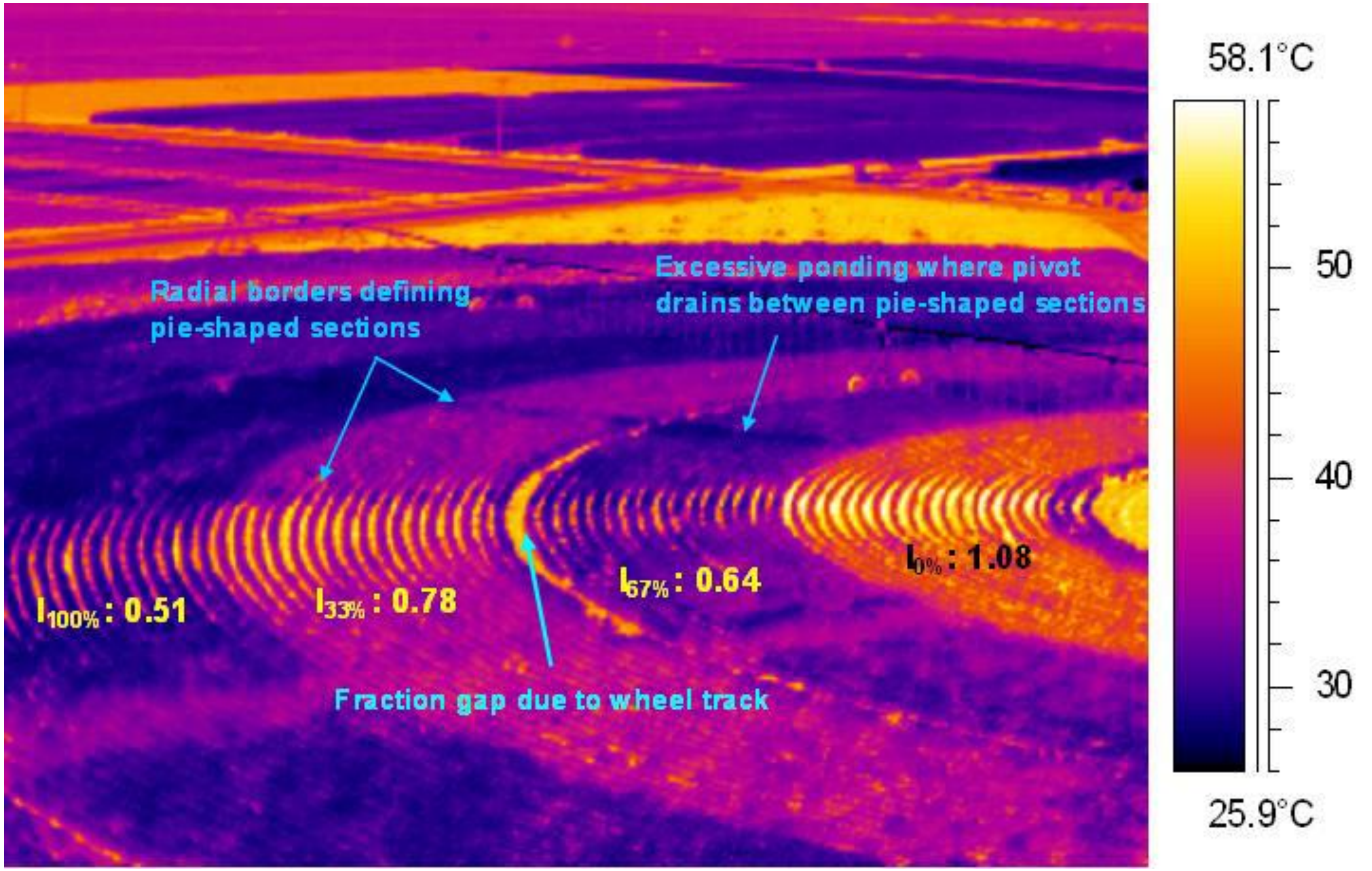
1=max



Chlorophyll absorbs blue and red light. Modern LEDs can be tuned to provide only these, so that all of their output is used for photosynthesis.

Sources: University of Queensland; *The Economist*

Variable-rate irrigation at Bushland, TX using a center-pivot and thermal infrared radiometers over cotton in 2012 at Bushland, Texas. Well-watered plants were 5–20°C cooler (blue) than water-limited plants (orange). (CSA News 2014)



Aeroponics: soiless cultivation.

Roots in air. Mist sprays provide water and nutrients. Unnatural. Questions: mist drop size, frequency of application, process of absorption. Efficient but expensive.

(first developed by NASA for Space applications)

Figure 3 *Arabidopsis* roots in potting substrate and aeroponic culture. Root morphology

Vaughan *et al. Plant Methods* 2011, 7:5

NASA aeroponic lettuce seed germination- Day 12

NASA aeroponic lettuce seed germination (close-up of root zone environment)- Day 19

Energy efficient polyhouse and aeroponic system for mini-tuber production of tissue cultured potato

Funding: NASF, ICAR

Institutes involved:

IISc, UAS, JNCASR - Bangalore

IARI - Delhi

CPRI - Jallandar

- Aeroponics for potato seed production from tissue culture plants
- High quality disease free seed tubers
- Makes economic sense
- Seed tubers –accounts for 40-50% crop production cost

Aim:

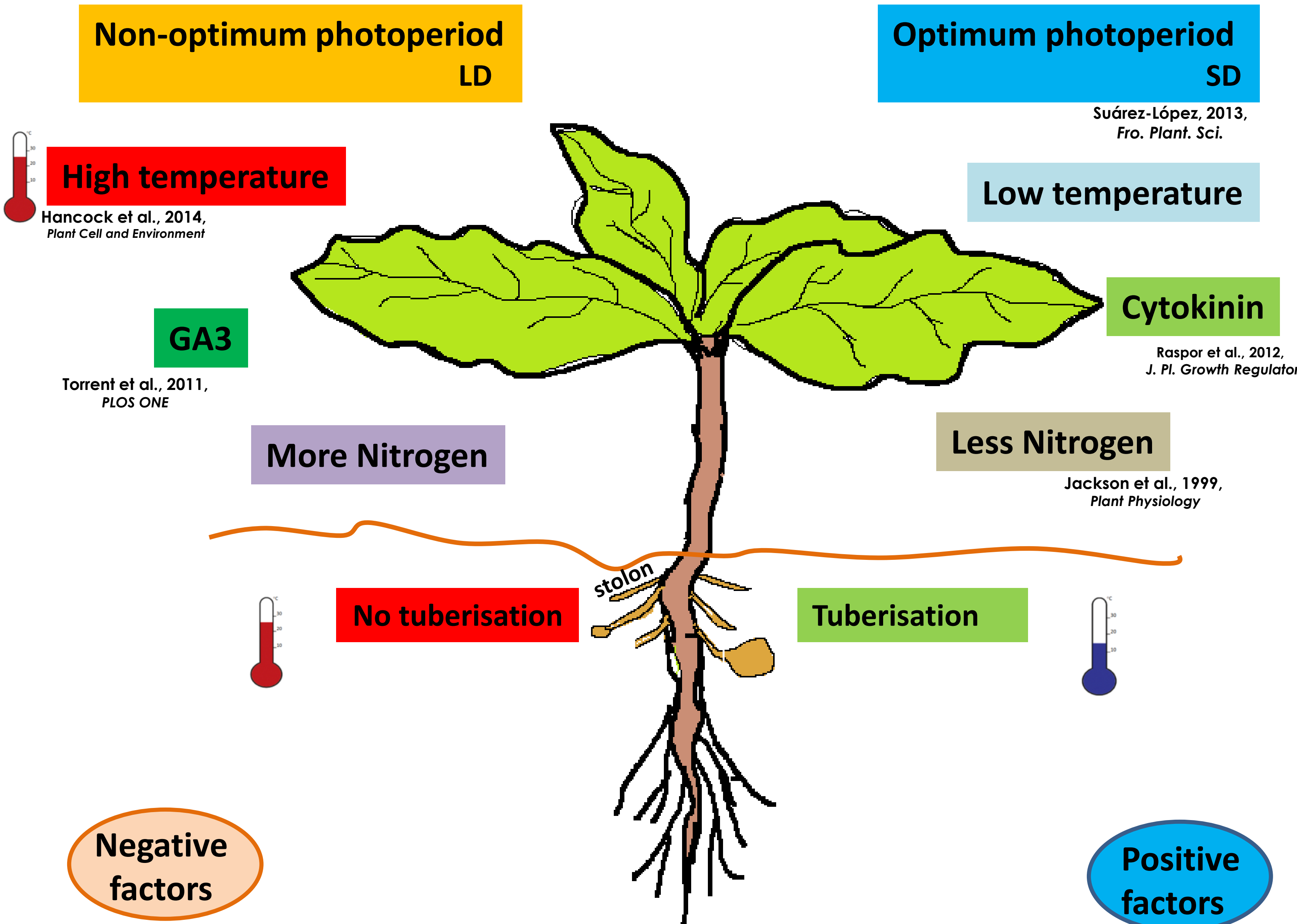
To make aeroponic technology for mini-tuber production

Energy Efficient
More productive
Cost effective
Adaptable to wide range of agro climatic conditions
Suitable across varieties / genotypes

For minituber production crucial is optimizing environmental variables for tuberization

- **Photoperiod & temperature major factors controlling tuberisation**

Factors regulating tuberisation - nutshell



The interaction of these factors regulate tuberisation

Goal is to optimise these individual components and

develop an integrated system /technolog

Polyhouse conditions Environment

Temperature, light

Factors regulating morphogenic process of tuberization & growth

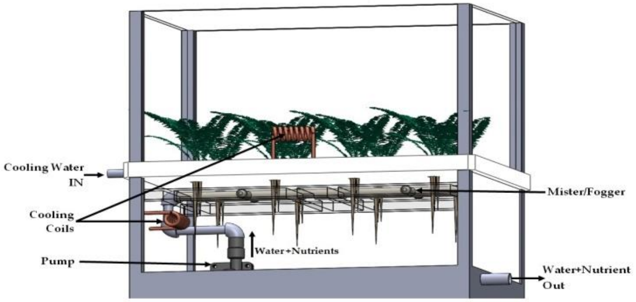
- Light quality
- Temperature
- Hormones
- Nutrition

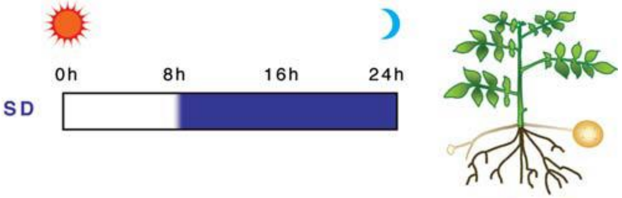
Aeroponic chamber variables

Temperature, misting, aeration

Fertigation

Water &
Nutrient delivery



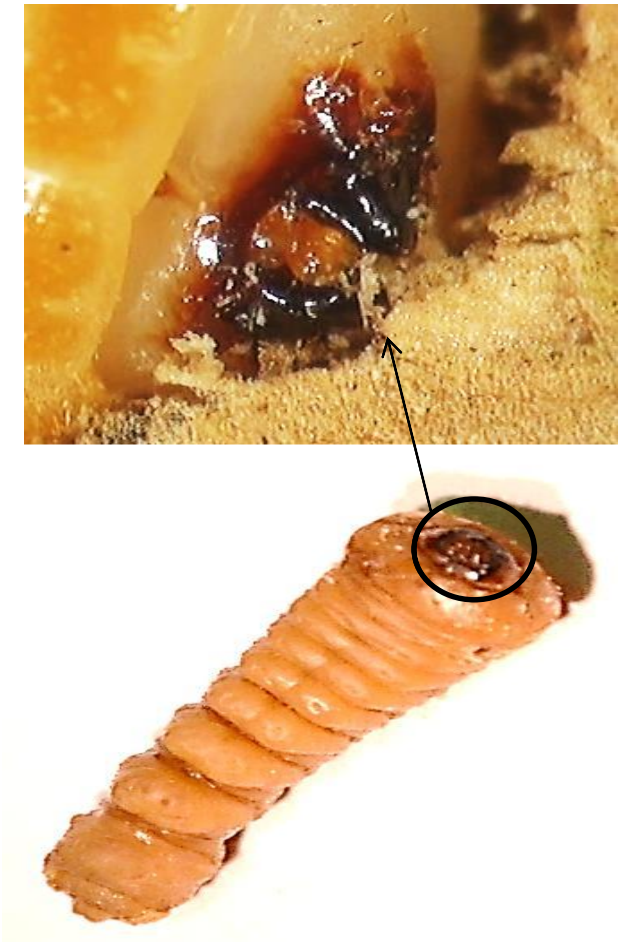


Supplementary light system

- Specific wavelengths to be used – 430, 660 and 730 nm
- 430 and 660 nm -> control vegetative growth
- 730 nm -> induce stolonisation
- Optimum Intensity will be obtained from experimentation

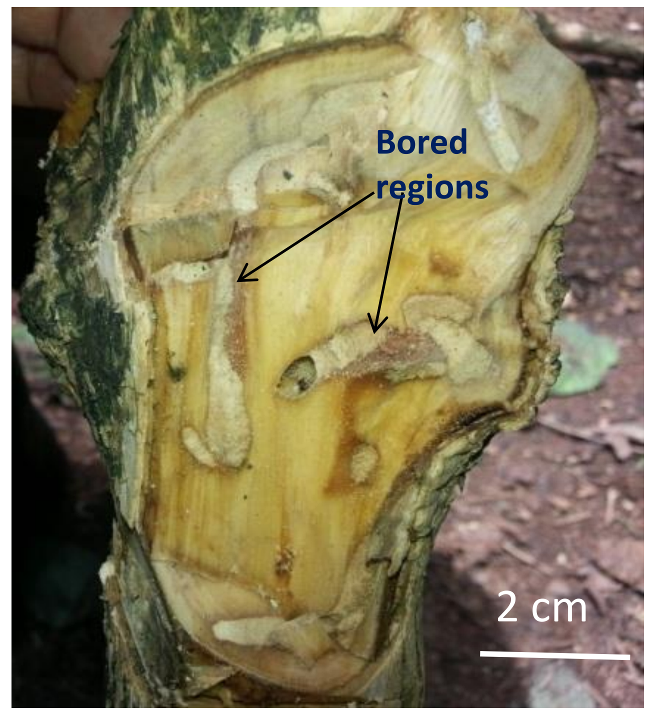
life cycle of white stem borer and infestation in Arabica coffee plants (huge problem)

(Namrata Gundiah, V R Sonti)

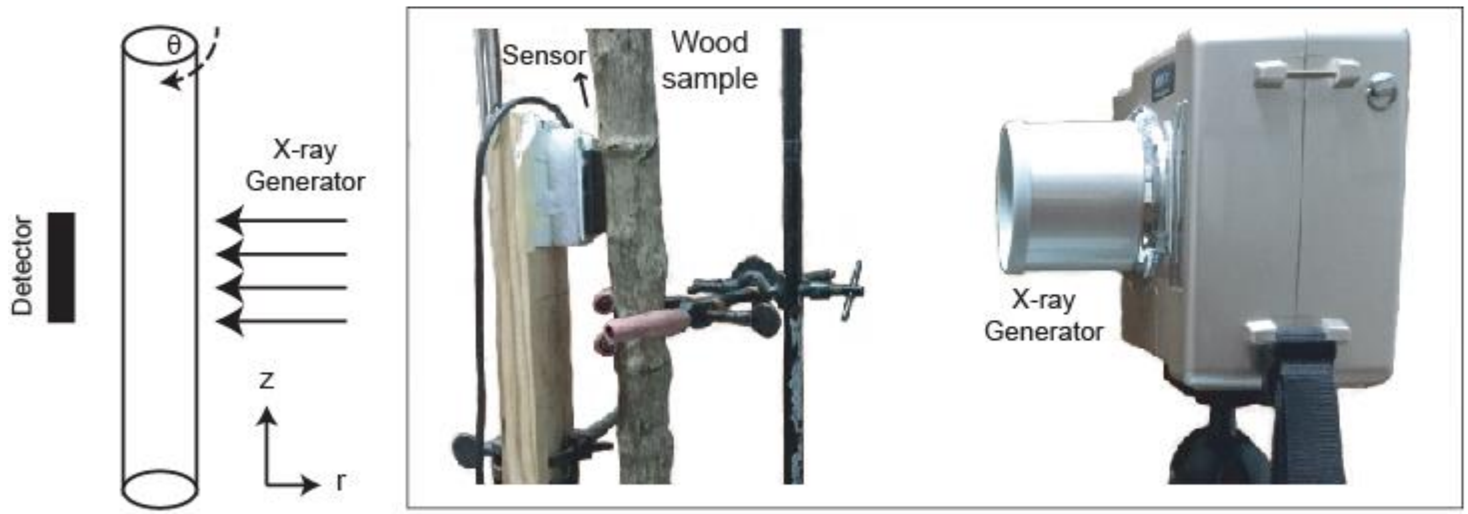


4th or 5th instar

Sectioned Infested *arabica* stem

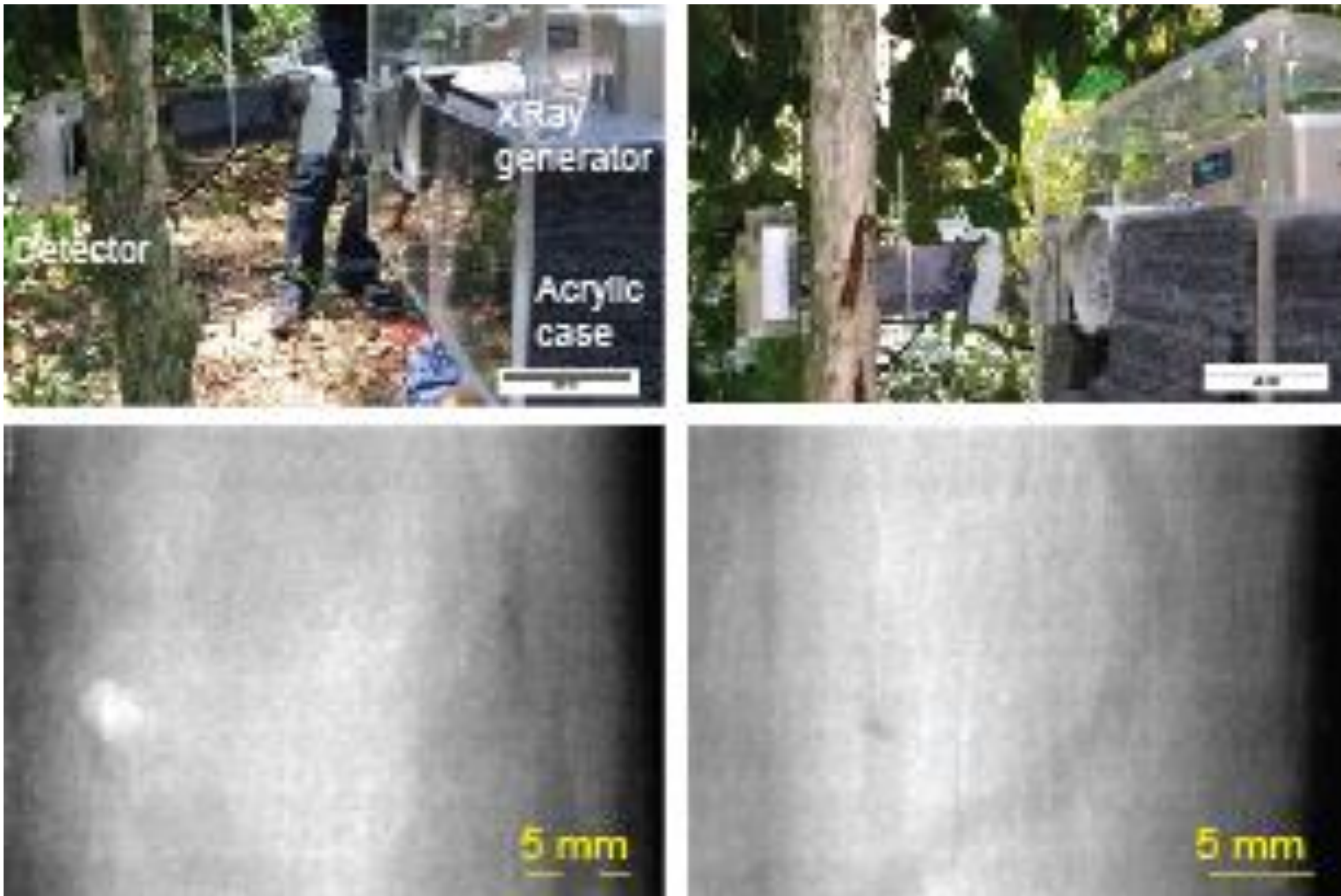


portable X-ray generators to visualize wood damage



Develop portable, minimally invasive sensing techniques to
detect presence of larvae in coffee stem and test for presence of wood damage

using the portable X-ray unit in field



Closing remarks

• Need for interaction, sorely missing now, between engineers, Design guidelines for optimized peri-urban polyhouse for Indian conditions, with efficient heat dissipation and sustainable usage of energy.
• Development of sensors, systems, image proceesing algorithms with intimate knowledge of plant physiology, soil.
• Small holdings problem: need innovative small farm machinery like planters, weeders
• Enough scope for fundamental research soil as an eco-system; absorption of pesticides at leaf level, physio-chemical model of a plant.
•Companies developing innovative solutions, technology for agriculture – very few
• Need to worry about ground reality

Sickle Innovations

(new start-up)

Products

- **Pre-harvest Solutions**
- Transplanter
- **Harvesting Solutions**
- Apple picker
- Mango picker
- Litchi picker
- Milking machine
- **Post-harvesting Solutions**
- Fruit grading solutions
- Coconut peeling machine

Thank you