Temperature and Drought Stress Management in Cash Crops-Emerging opportunities for scientific interventions

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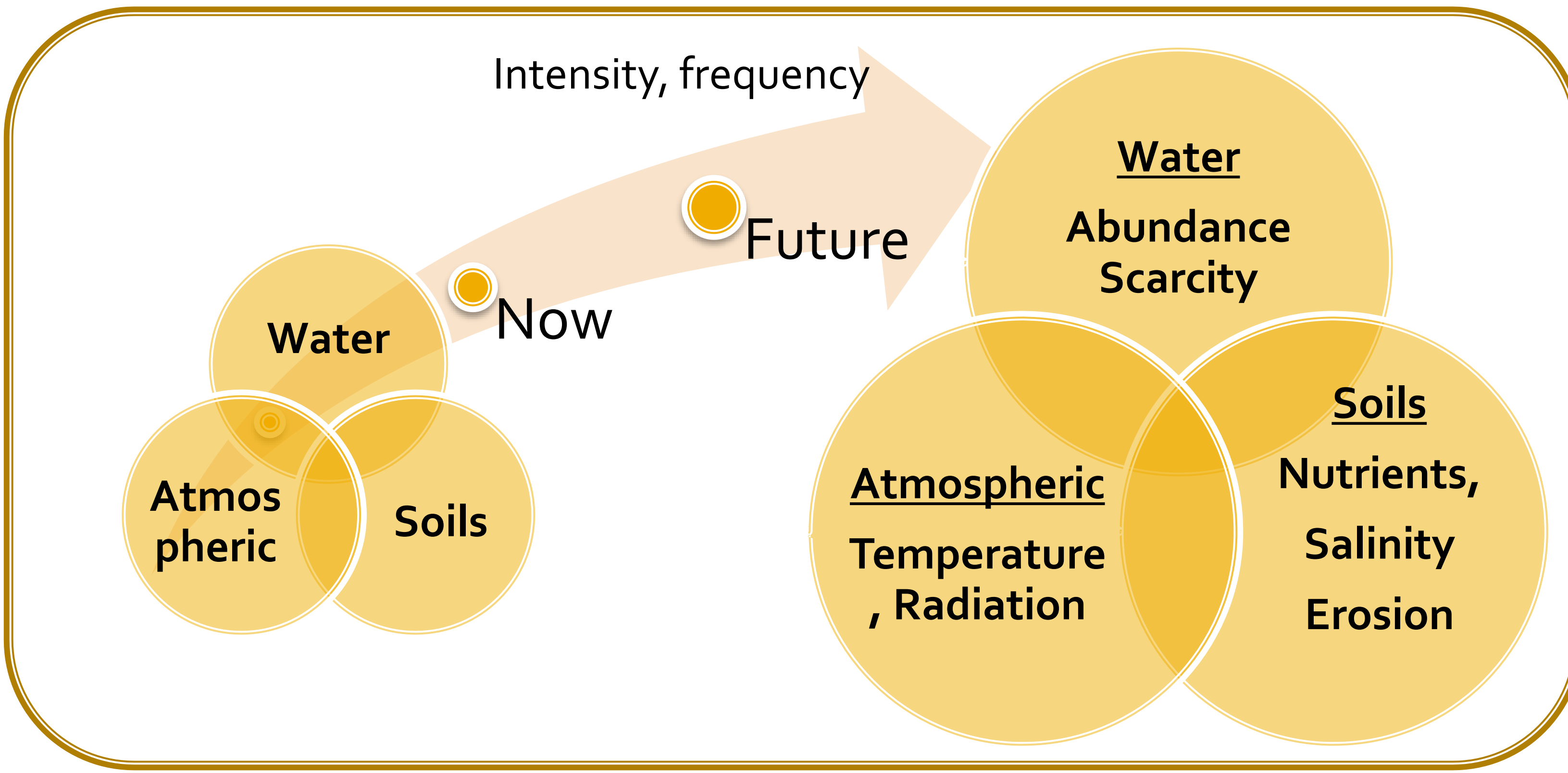
Outline

- Temperature and drought trends
- Vulnerability of commercial crops
- Physiological response
- Management options
- NIASM in action
- Summary
- Acknowledgement

Climate change for crops implies
Deviation from optimum agronomic conditions

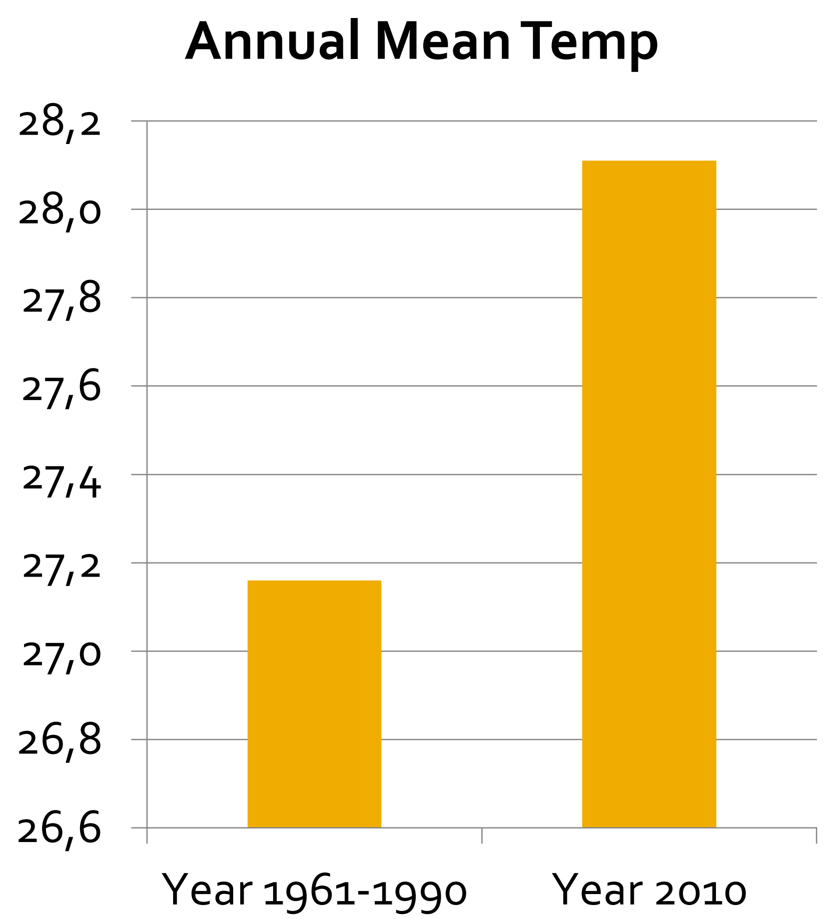
Sub or supra optimal level



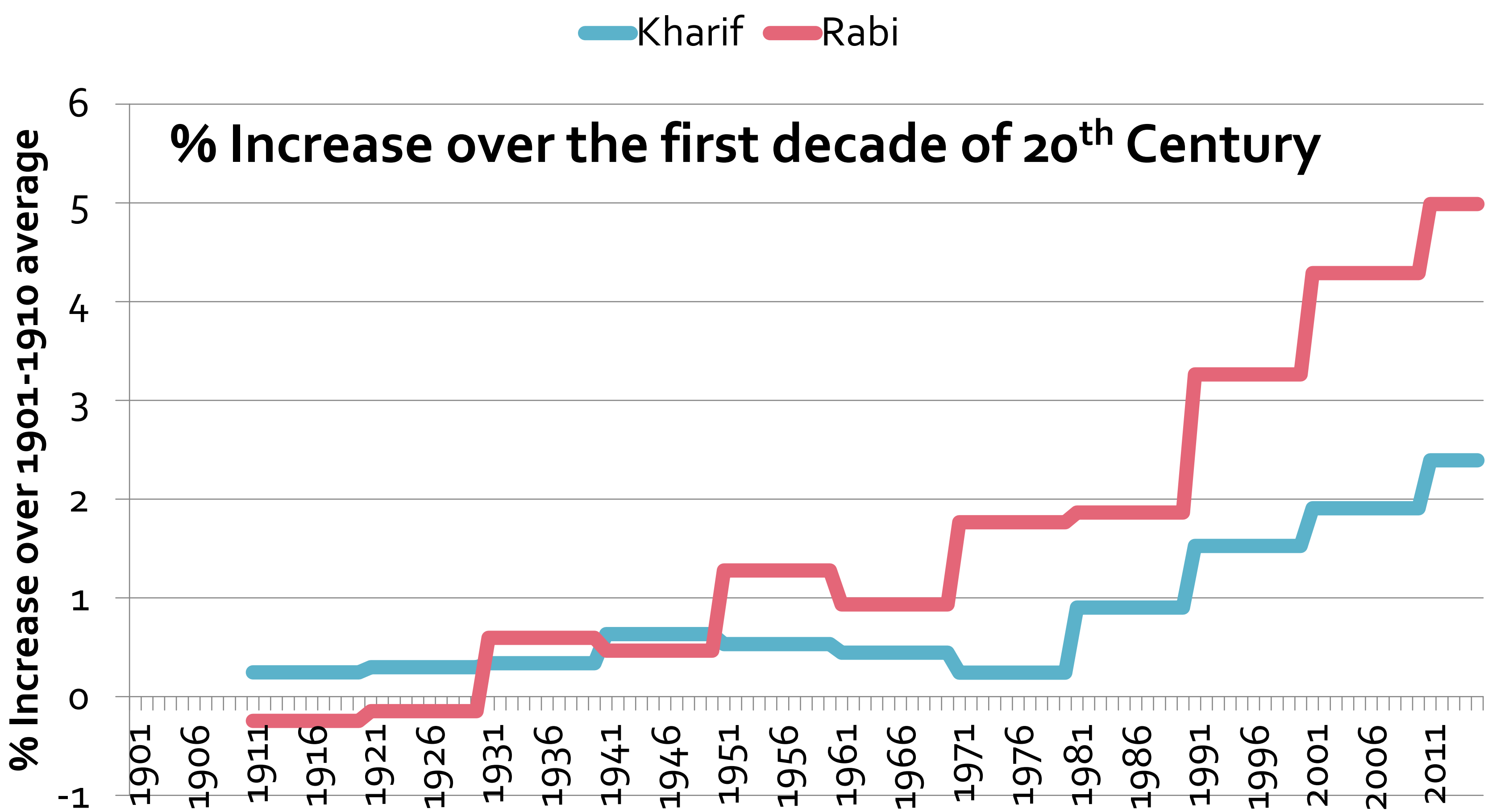
Time

High temperature threat: Facts and Predictions

- **Fact:**
  - 2010, warmest year on record since 1901.
  - Eight out of ten years of the last decade were warmer.
- **Predicted increase minimum and maximum temperature Rabi season in south Asia**
- **by 2020**
  - -1.08°C and 1.54°C
- **by 2050**
  - 2.54°C and 3.18°
- **by 2080**
  - 4.14°C and 6.31°C
    - (Lal *et al*. 2001).

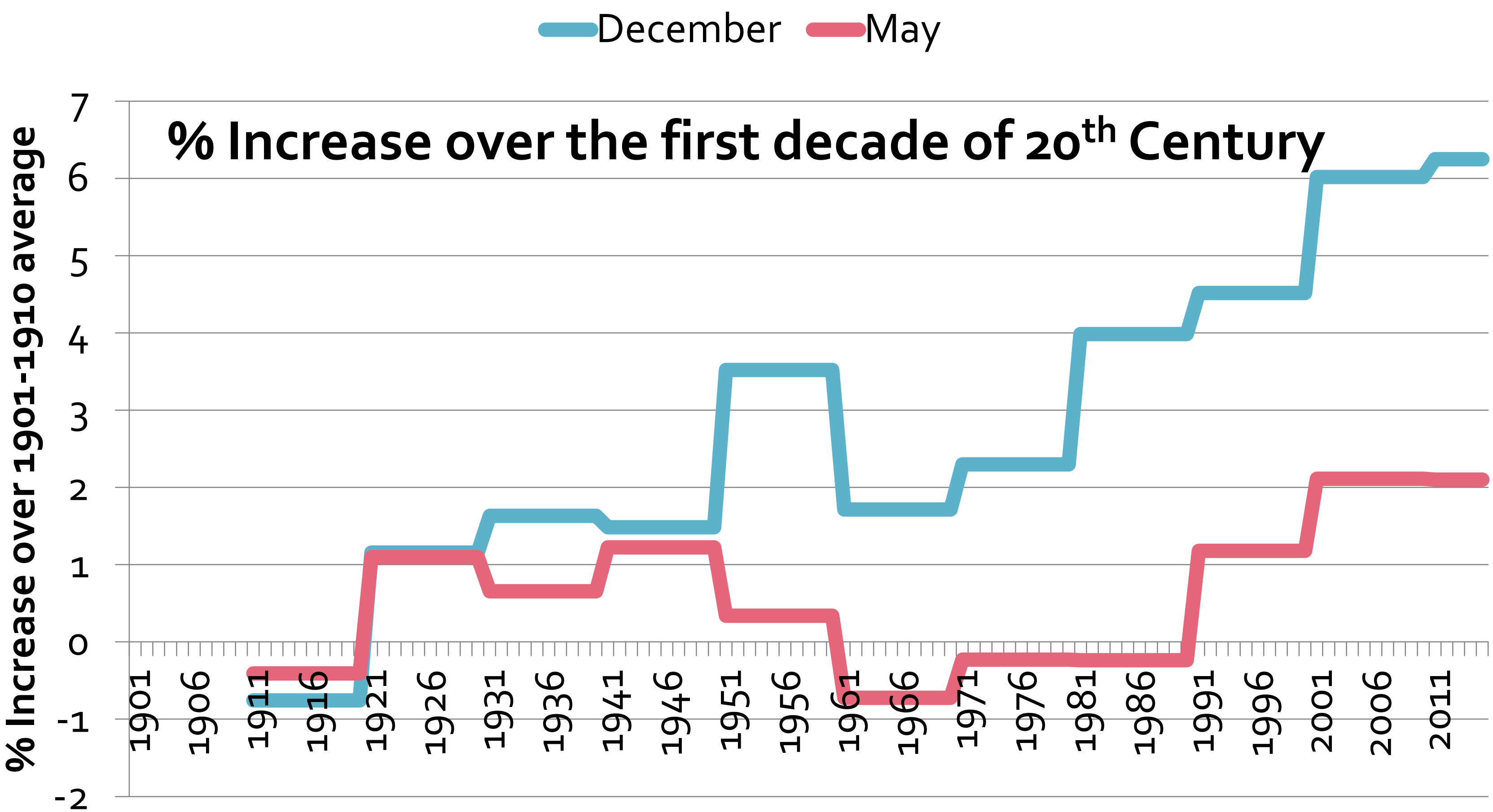


Rabi season (October –April) becoming more hotter in India



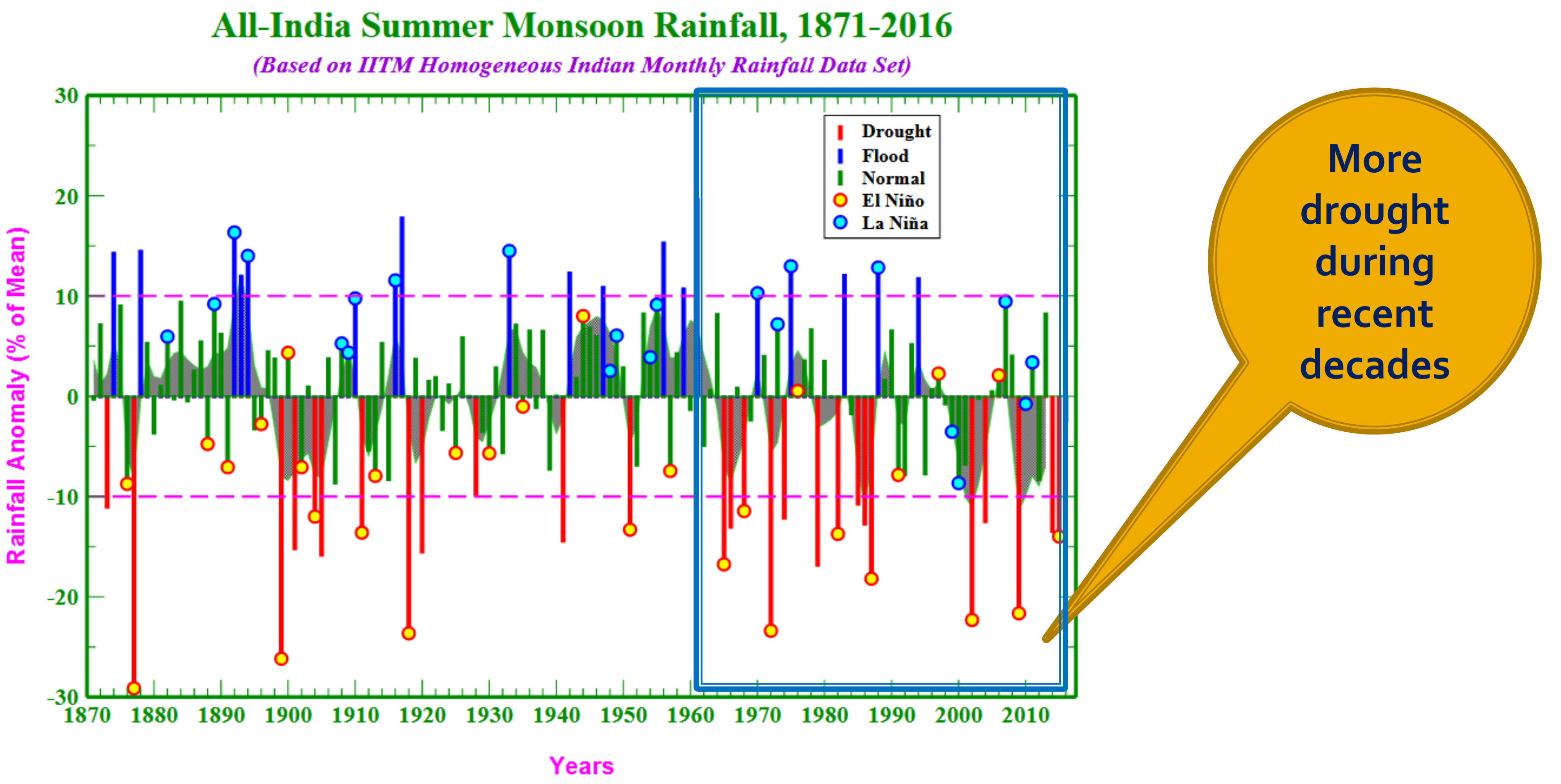
Rane et al (unpublished)

Cooler month(December) warming more rapidly in India

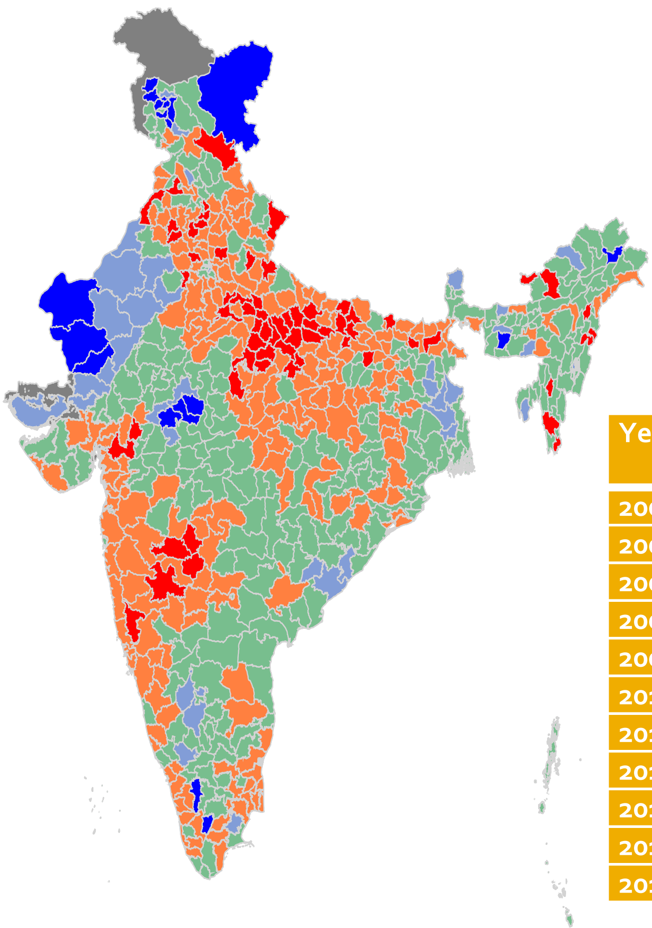


Rane et al (unpublished)

Water Stress:
A glimpse at drought during 140 years



Impact of recent drought (2016)



Deaths due to heat wave in India from 2005-15

Year	No. of deaths
2005	277
2006	100
2007	416
2008	237
2009	353
2010	264
2011	Nil
2012	800
2013	1393
2014	535
2015	2500

According to the GoI response filed in the Supreme Court on 19th April 2016, at least 33 Crore (**330 million) people** from 255,923 villages across **254 districts** (out of the total 688) **in 10 states** (out of the total 29) are affected by drought in 2016. - **That's more than a quarter of the population of India!**

Slide from UNICEF presentation

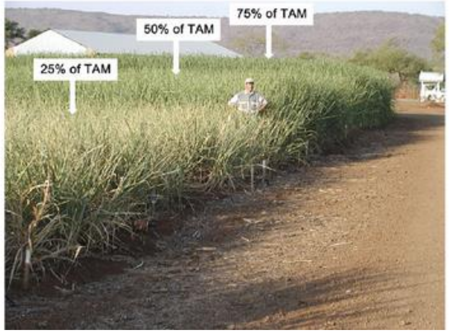
Effect of High Temperature on Crops

- Indirect
  - Increase in water loss
    - evaporation -soil
      transpiration -plant
  - Desiccation in absence of soil moisture
- Direct
  - Flowering and fruiting severely affected
  - Pollen, pollination and fertilization affected
  - Enzyme activities are affected

1 °C degree rise in temperature may increase water demand by more than 10%

Effect of HT and Drought on Sugarcane

- Drastic reduction in production during drought years
  - Eg Maharashtra state
- Water guzzling plant has to depend on drips in future
  - Maharashtra sugarcane growers implementing
- Impact on plant
  - Leaf and plant size
  - Leaf senescence
  - Effect on physiological processes including photosynthesis



Lopez et al.(2011)Experimental Botany 62(9):3135-53

Effect of Drought on Sugarcane

- Data reveal drastic reduction in production during drought years
  - Eg Maharashtra state

- production (lakh tones)
  - 2016-17 drought -372.45
  - 2014-15 normal -929.00
  - 2015-16 normal- 741.68
  - 2004-05 drought 204.00

- Productivity (tones/ha)
  - 2016-17 drought - 65
  - 2014-15 normal - 88
  - 2015-16 normal - 89
  - 2004-05 drought - 63

  - (unpublished)

Lopez et al.(2011)Experimental Botany 62(9):3135-53

Cotton: Grown by farmers even at the risk of drought in India

- out of the 14 Kharif crops
  - (paddy, maize, jowar, bajra, ragi, tur, moong, urad, groundnut, soyabean, sunflower, sesame, nigerseed and cotton)
- cotton has the maximum absolute profit

(‘Price policy for Kharif crops -2014’)

Cotton: Grown by farmers even at the risk of drought in India

- About 65% of the cotton growing area
  - rainfed
  - low productivity
  - high year-to-year variations coupled with risk induced low input usage.
- If monsoon fails
  - Resowing
  - Enhance cost of cultivation
- Technologies emerging
  - Preplanted in poly- bags
  - Drip irrigation??

Making the plant survive is challenge

https://www.gettyimages.in/detail/news-photo/july-25-wharton-county-texas-usa-cotton-plants-killed-by-news-photo/51059905#/july-25-wharton-county-texas-usa-cotton-plants-killed-by-the-worst-picture-id51059905

Effect of high temperature and drought on -Cofee

- High temperature
  - Optimum temperature 18-21°C
  - >23°C- rapid growth and ripening –poor quality
  - >30°C- abnormal growth, leaf yellowing, flower abortion
- Dry spells
  - Early senescence of lower leaves
  - Early flowering and reduced yield
- Common impact
  - Oxidative stress

Only 70% of normal rainfall -25 % reduction in production in the 2016/17 crop year, the lowest since 1998/99 (predicted)

Braz. J. Plant Physiol., 18(1):55-81, 2006

Water essential for nutrient uptake
Macronutrient deficiencies in grape

P-deficiency

K-deficiency

Mg deficiency

Black leaf: Excess Na & Low K

Physiological disorders in grapes

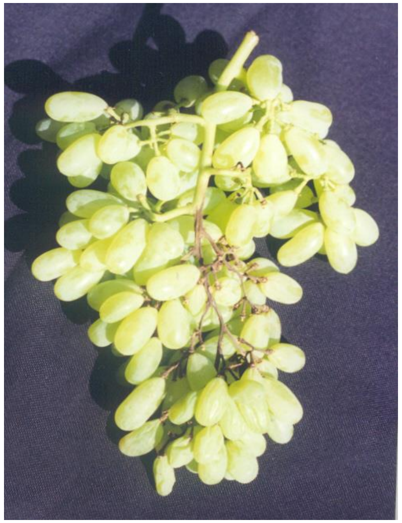
Hen & chicken

Shot berries

Physiological disorders

Chloride toxicity

Berry cracking



Bunch stem necrosis

Physiological disorders due to high temperature

Sun burn

Effect of water deficit and high temperature on Pomegranate

- Effects
  - Fruit cracking
  - Sun scald/ sunburn
  - Blackening of arils
- Causes
  - improper irrigation,
  - environmental factors
  - boron deficiency.
  - Deficiency of calcium and potash

  More in Rajasthan & some part of Maharashtra.

- Fruit cracking
  - 63% - spring crop (January-June),
  - 34% -the winter crop (Oct-March)
  - 9.5% -rainy season crop (July-Dec).
    - Pant (1976) and Sonawane et al. (1994)

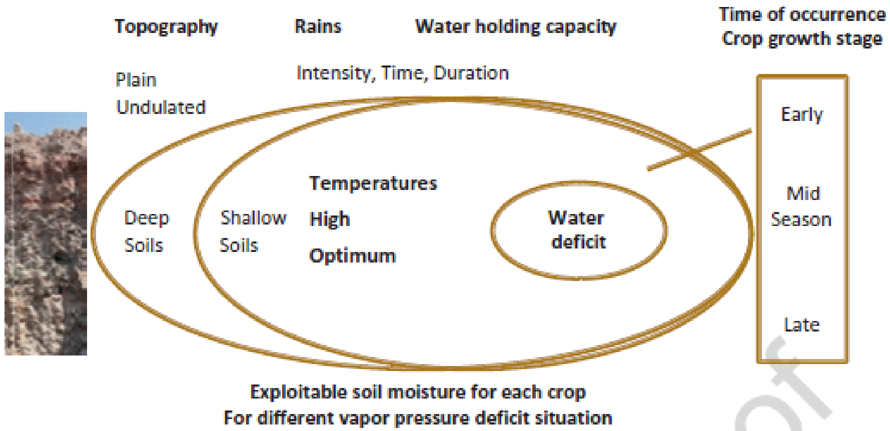
External application of bioregulators and nutrient- as a solution

Fruit cracking

- Fruit cracking can be reduced by
  - Micronutrients
  - Growth regulators (Khatri et al. 2001
  - Boron at 0.2% (Singh et al. 2003)
  - Pinolene (an anti transpirant) at 5% (Bacha and Ibrahim 1979)
  - Regular irrigation & Use of mulch .

Drought stress :
Key points for climate smart agriculture

- Long dry spells
- Less rainy days
- Intermittent drought
- Early drought
- Terminal Drought



Management Options

Smart management??

Crop Management for Climate Resilience

Smart Plants??

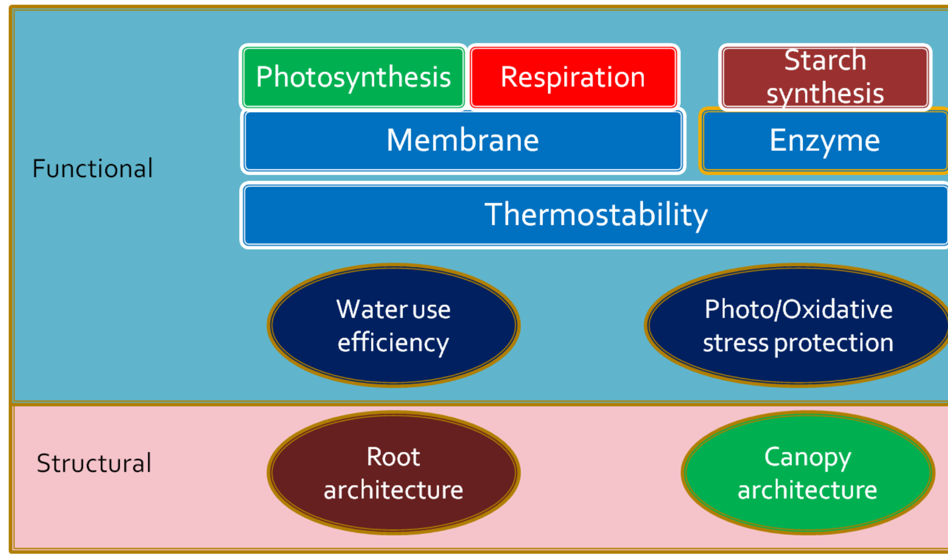
Climate Smart Plant Phenotype

Rane and Minhas(2017)

Climate smart crop-need of the hour

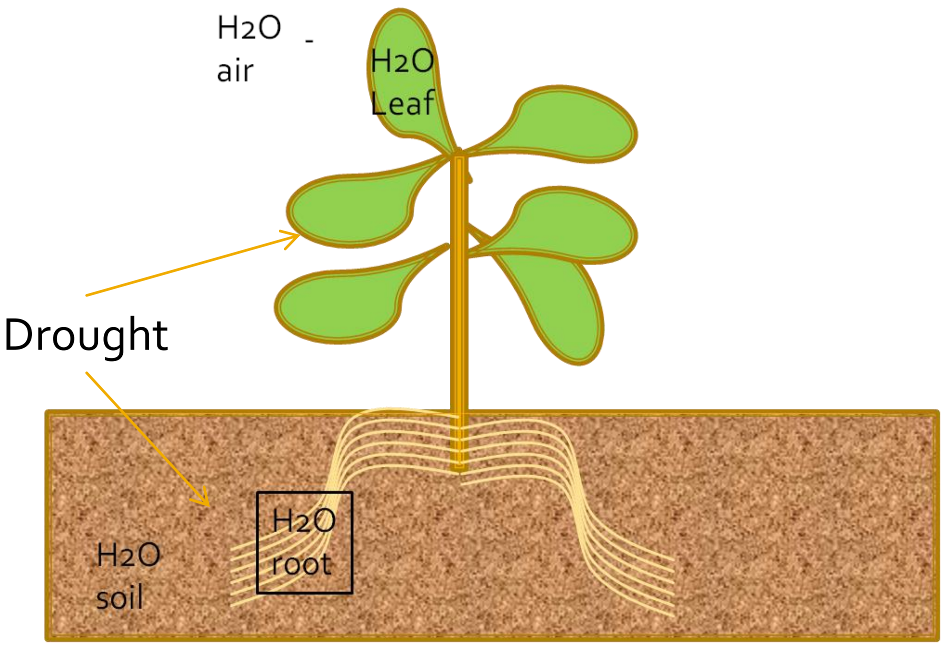
- Understand the physiology
  - To manage the crop
  - To improve inherent tolerance

make plant comfortable



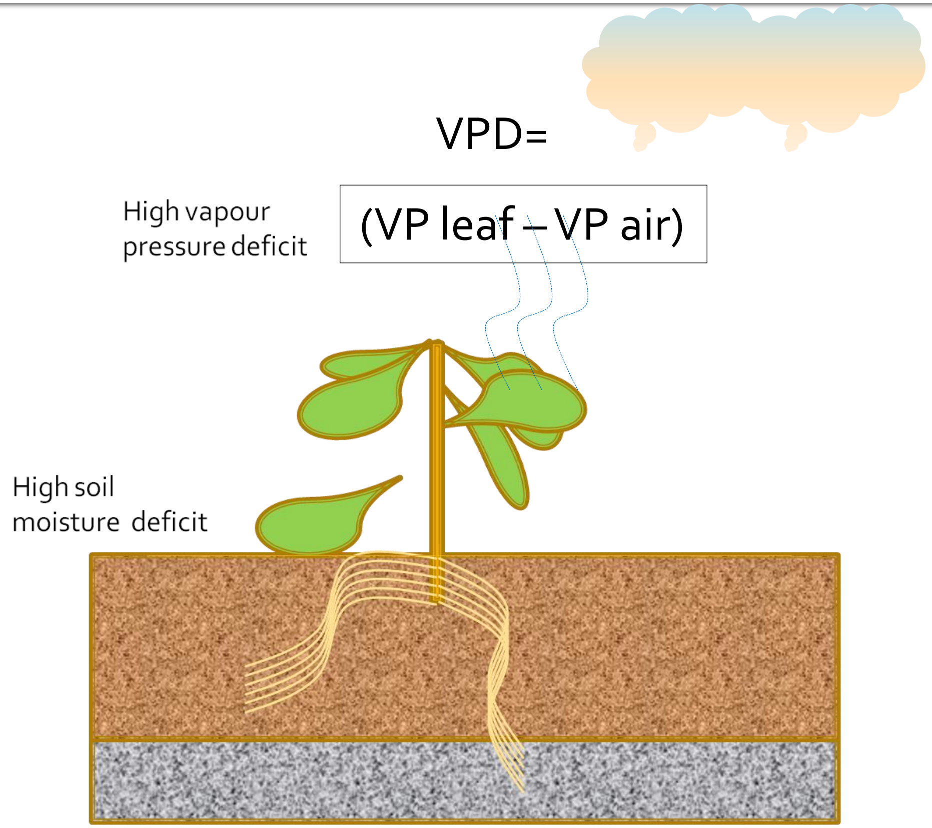
How plant respond to drought situation

- Plant sense drought at least in two ways
  - A. The difference in moisture content in air and the plant leaf(Vapour Pressure Deficit)
  - B. The dryness of soil



How plant respond to drought situation

- Plant try to
  - A. Reduce the water loss from leaf
    - Closing stomata
    - Leaf drooping
    - Leaf folding
    - Leaf shedding
  - B. Start growing more roots to extract soil water
    - Deeper root
    - More branches



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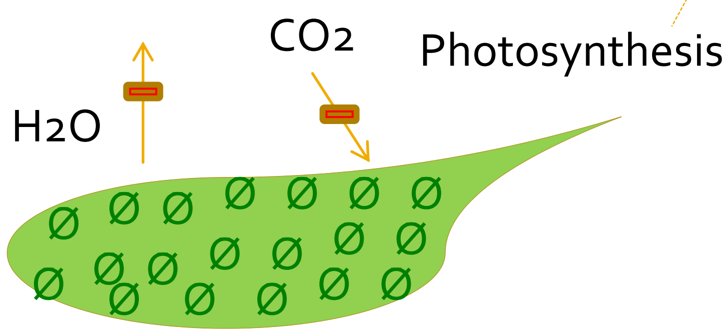

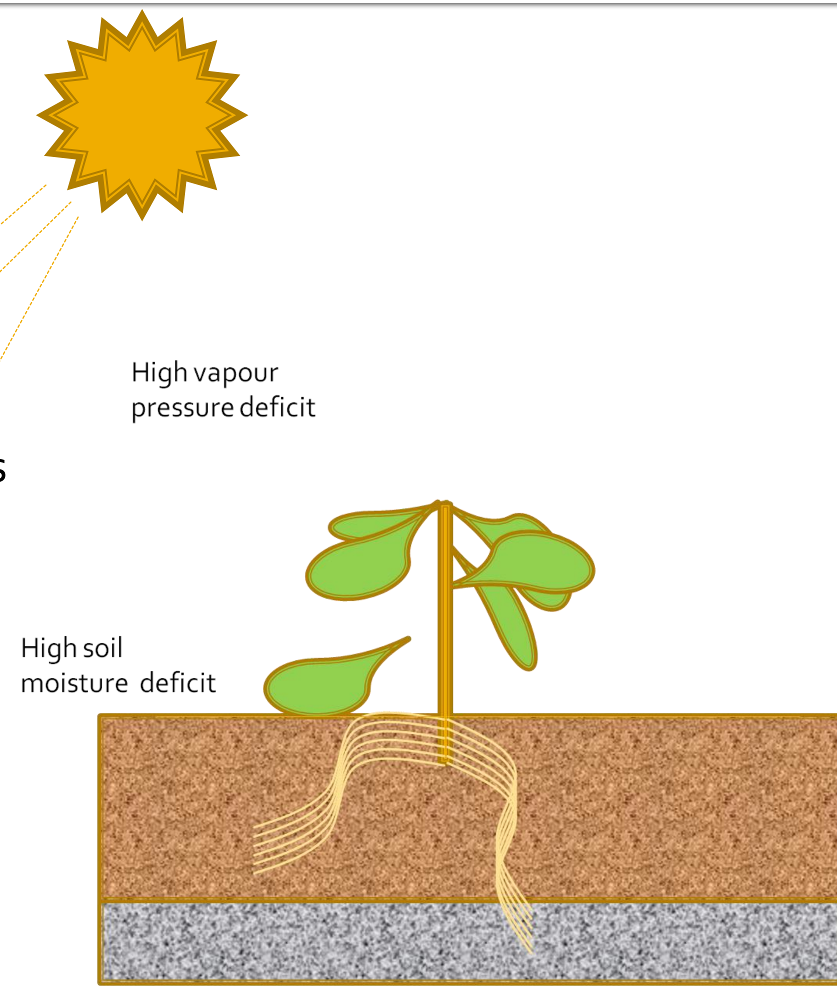

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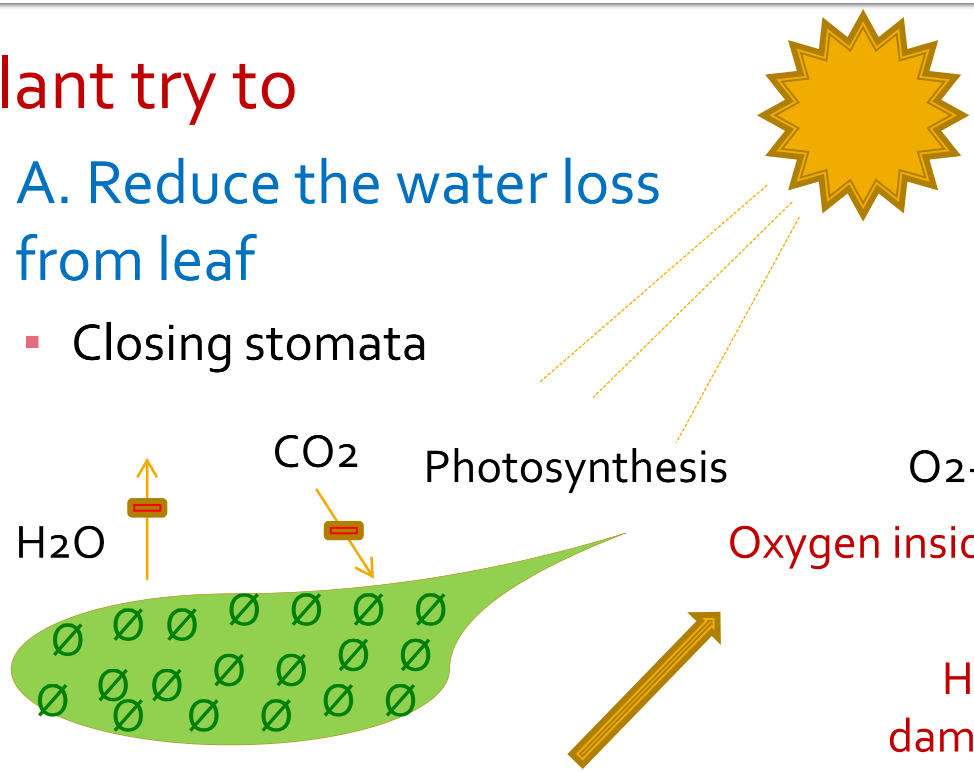

O_2-------------O^-

Oxygen inside leaves become Super Oxygen

High energy molecules damage plant cell and tissue

Plant death

Energy trapped from Sun Remains unutilised

How plant respond to drought situation

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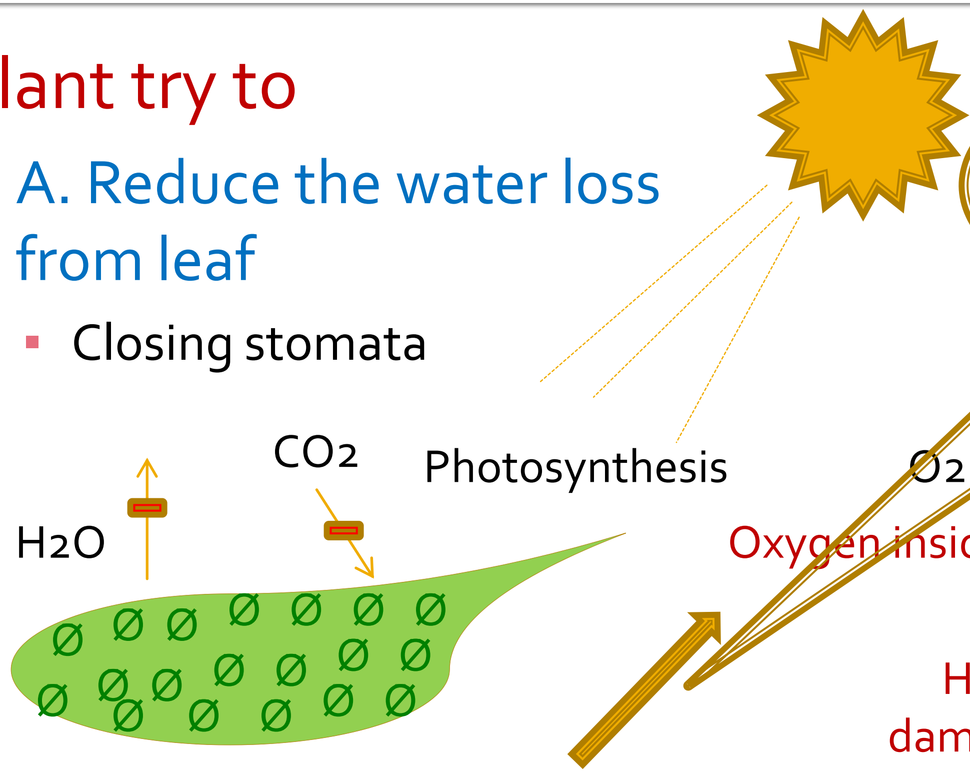

Antioxidative system with endogenous molecules or external application can stop this process

O_2-------------O^-

Oxygen inside leaves become Super Oxygen

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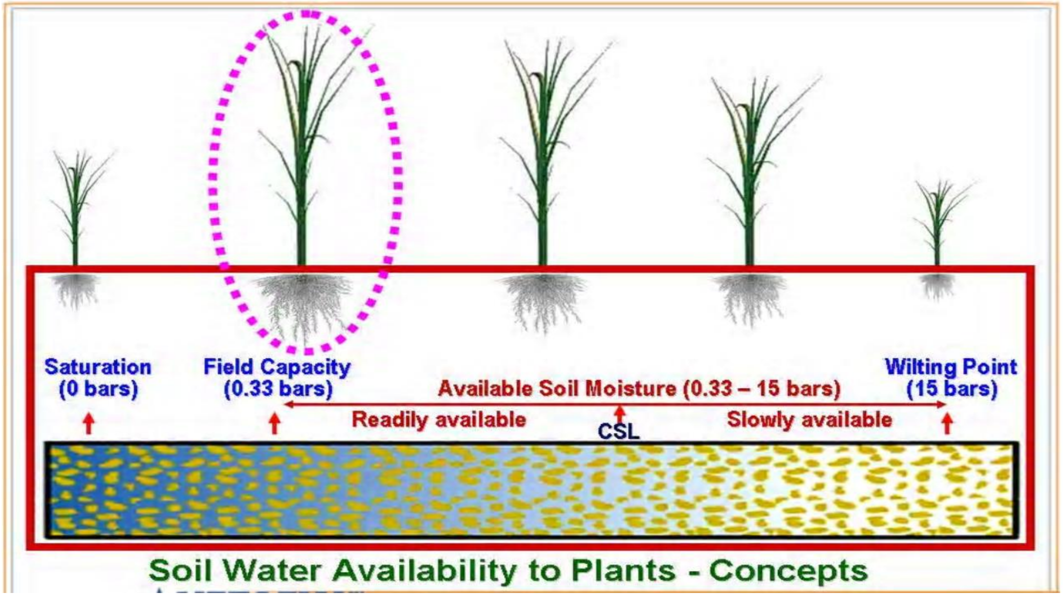
Plant death

Energy trapped from Sun
Remains unutilised

Water saving irrigation



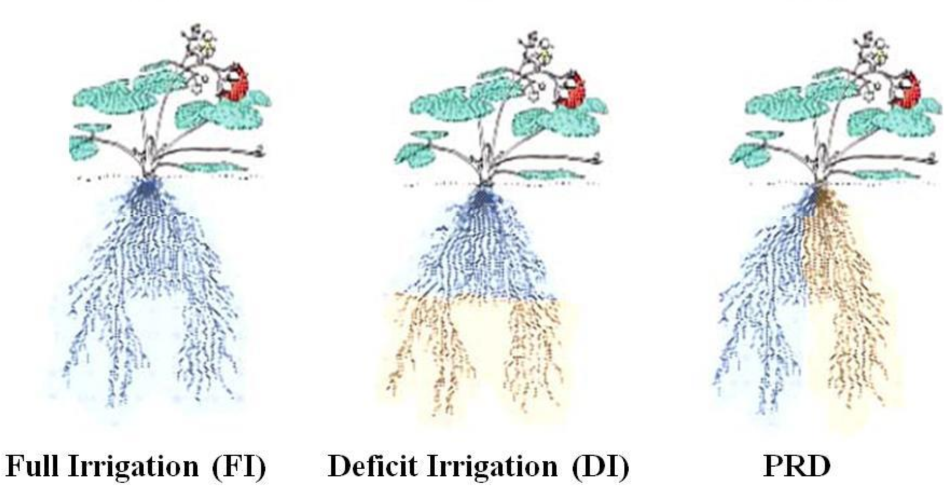
Full irrigation (FI): to obtain optimal soil water dynamics, always below FC

RDI - 50-70% water of full irrigation to apply to the whole root system

PRD - one side of the row should be irrigated while the other kept dry. Shifting usually done when soil water content in dry side is reduced for 30% comparing to the wet side (after *5-10 days)*. *PRD* plants should received 50-70% of full irrigation.

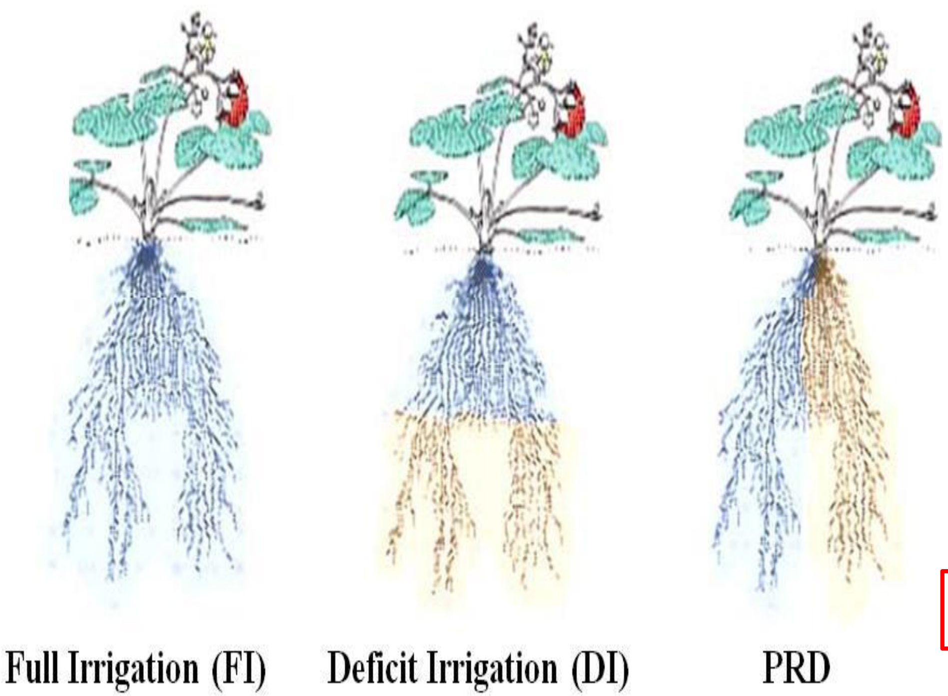
Managing available water for irrigation

Biochemicals produced in roots act as signal for closing stomata and saving water



20 to 40% water saving without yield loss depending on crop and soil type

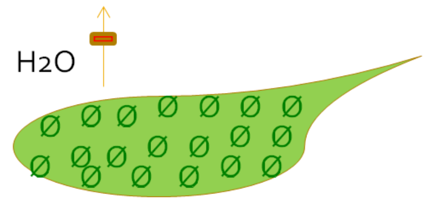
Managing available water for irrigation



ABA

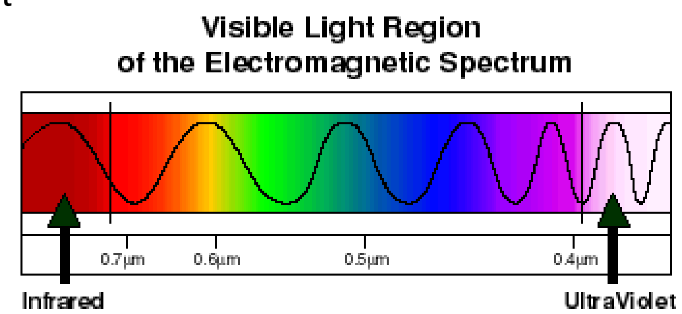
Stomata Close

Less Water loss



Imaging Technologies to monitor plant responses to drought and HT

- **Off-the-shelf technology**
  - Colour images
    - Plant area, volume, mass, structure, phenology, ontology
    - Senescence, chlorophyll content
    - Seed yield, agronomic traits
  - Near IR imaging
    - Tissue water content
    - Soil water content
    - Grain quality
    - Stem carbohydrates
  - Far IR imaging
    - Surface temperature
  - Fluorescence imaging
    - Physiological state of photosynthetic machinery



- **Future technologies**
  - X-ray images of roots in soil
  - High resolution NMR-based imaging of roots in soil
  - Terahertz imaging of water content
  - New software for new data mining
  - Second generation phenomic measurements

(Adopted from from Mark Tester: Australian Plant Phenomics)

Advances in instrumentation facilitate access to non invasive phenotyping

LemnaTec, Germany
Crop Design

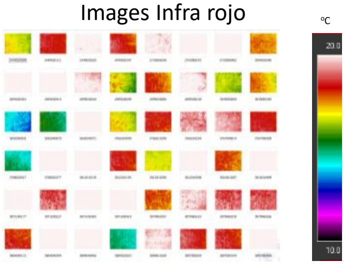
Plant MRI

Research Centre Julich, Germany

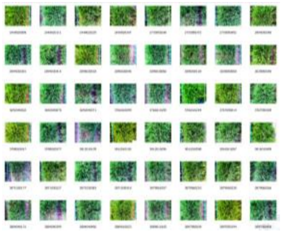
Imaging accelerates characterization of plant responses

Identifying cool genotypes out of 500 lines in 30 minutes

Infrared Image
Images Infra rojo



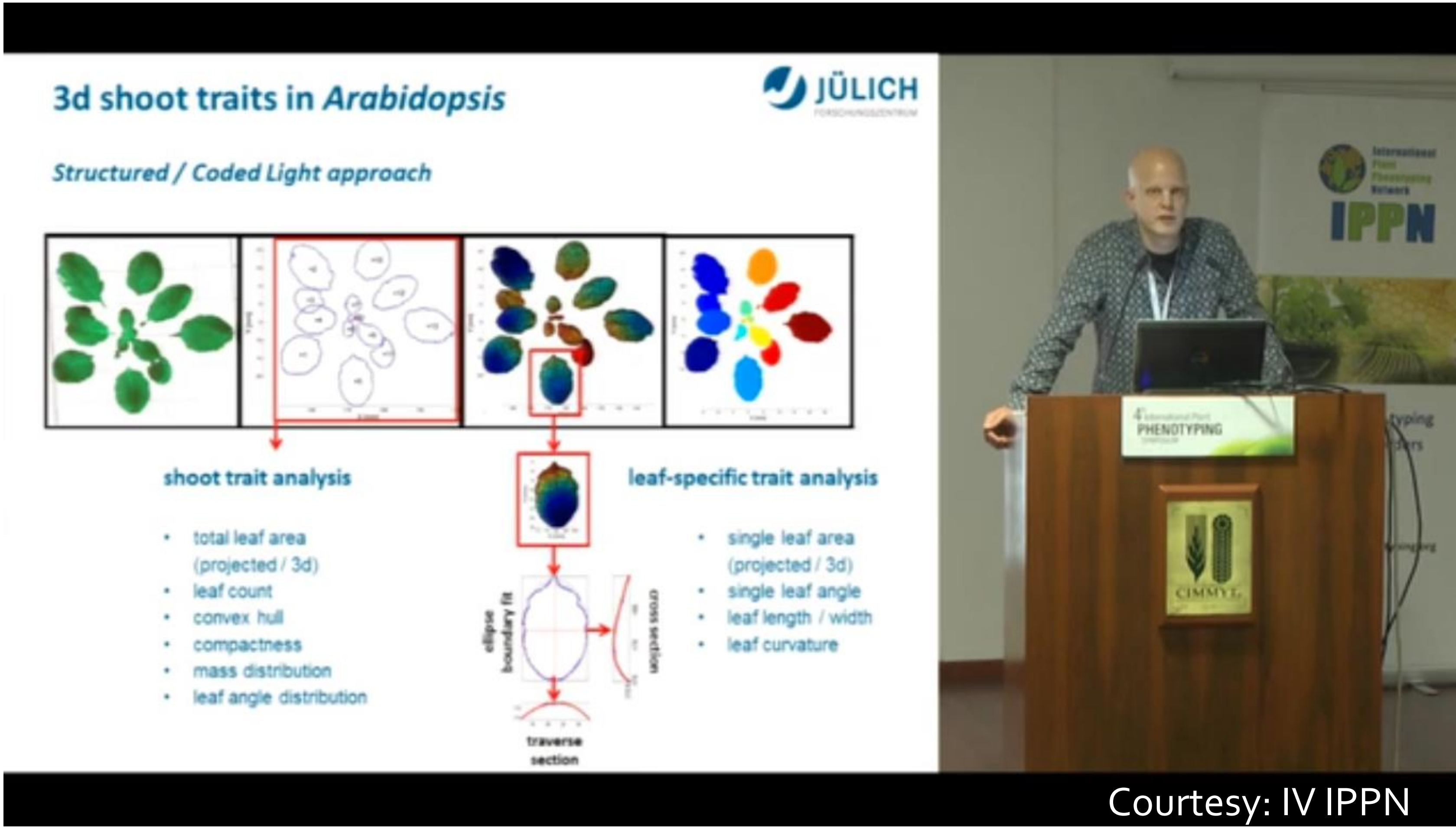
Visible Image



Rane et al (2010); CIAT Phenotyping
Crop Science,Intnl. Congress, LA, USA, Nov, 2010

Surge in power of science

Understanding shoot response to environmental factors

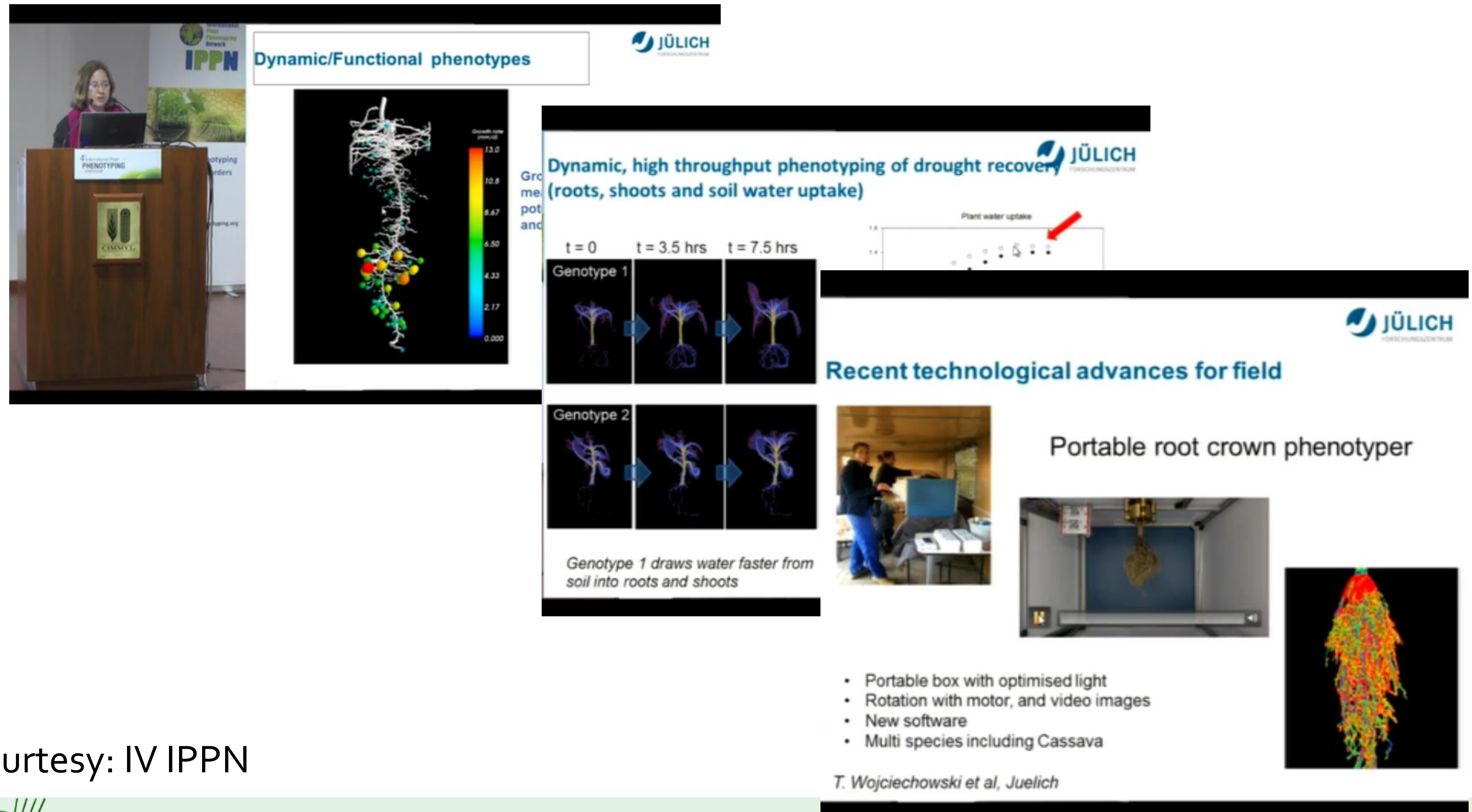


Courtesy: IV IPPN

IoT and M2M to handle big data University of Tokyo, Japan

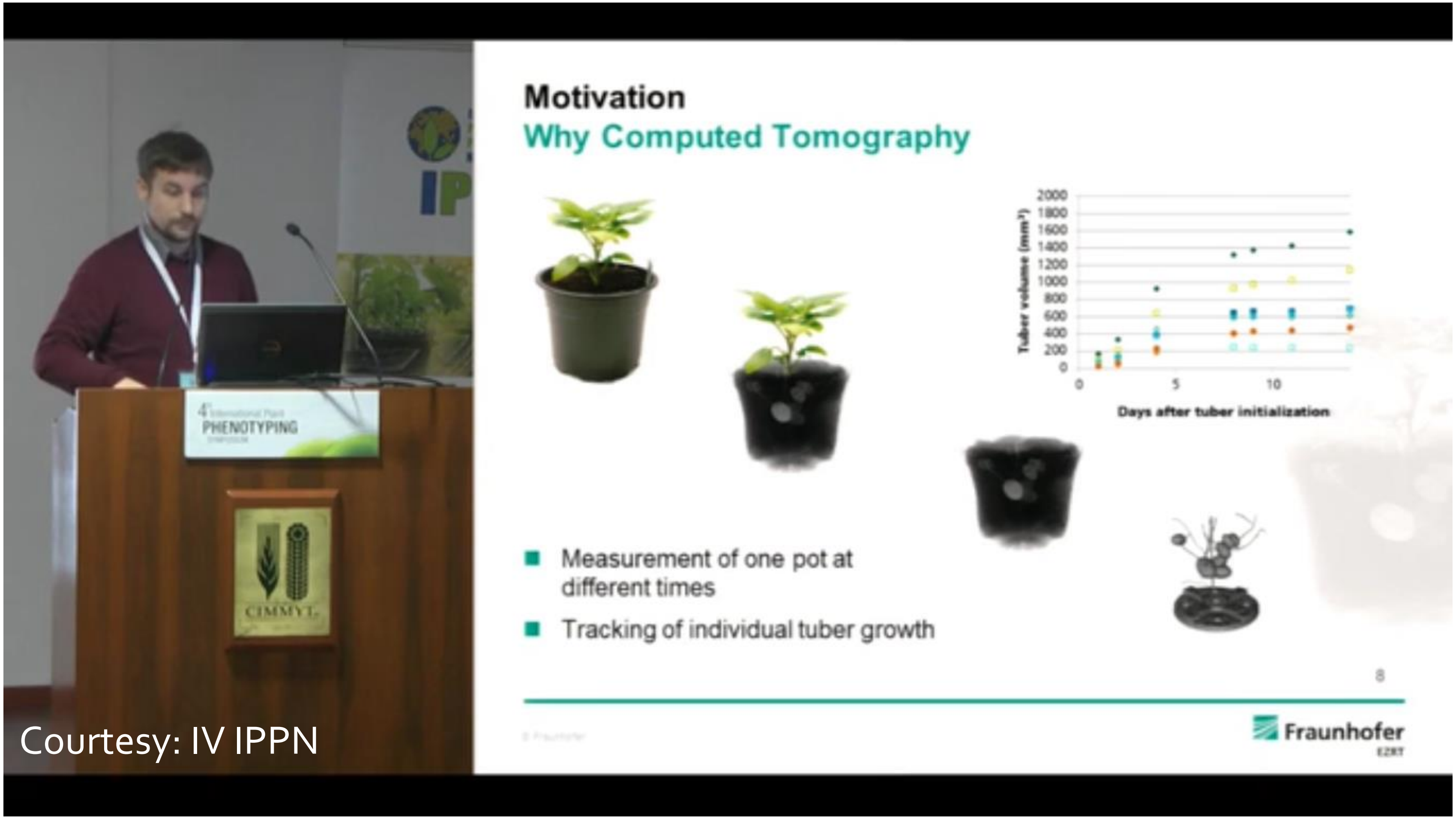
- Site specific data
  - soil moisture, temperature and radiation
- Remote sensing data
  - by UAV and satellite
  - integration as a big-data on cloud services.
- Big-data for relationship among genome and phenome.
  - Field Phenomics and smart farming -complementary.

Imaging tools for understanding plant root dynamics



Courtesy: IV IPPN

Answering how the potato grows ? Without disturbing the soil



National Institute of Abiotic Stress Management

NIASM(2009)

An unique institute in the making

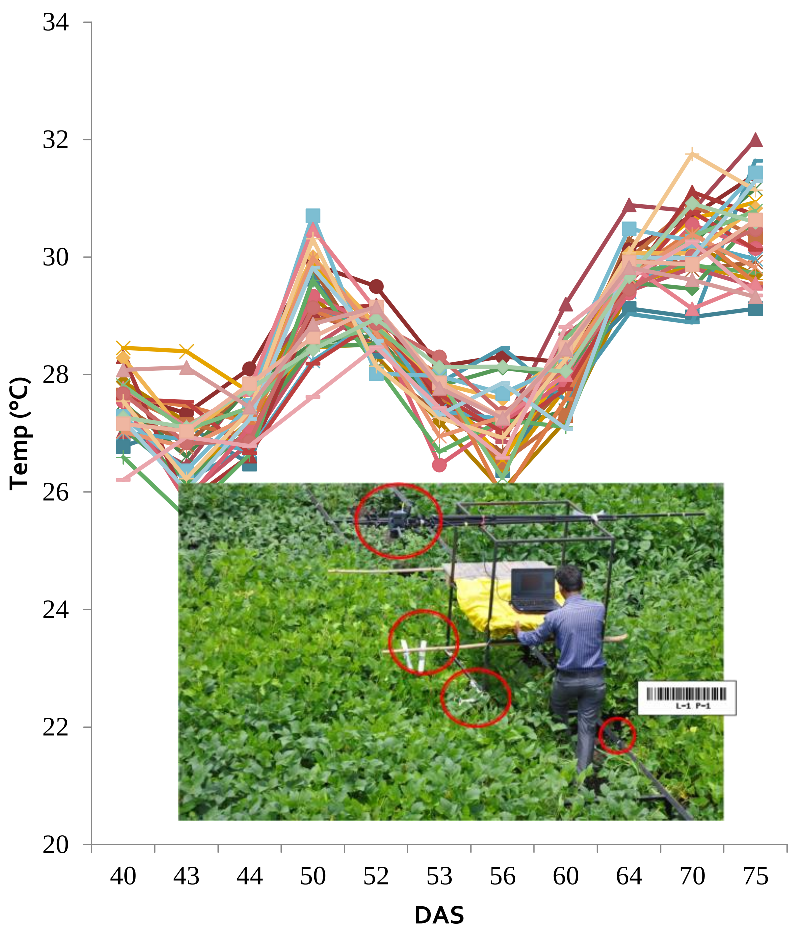
Abiotic stress

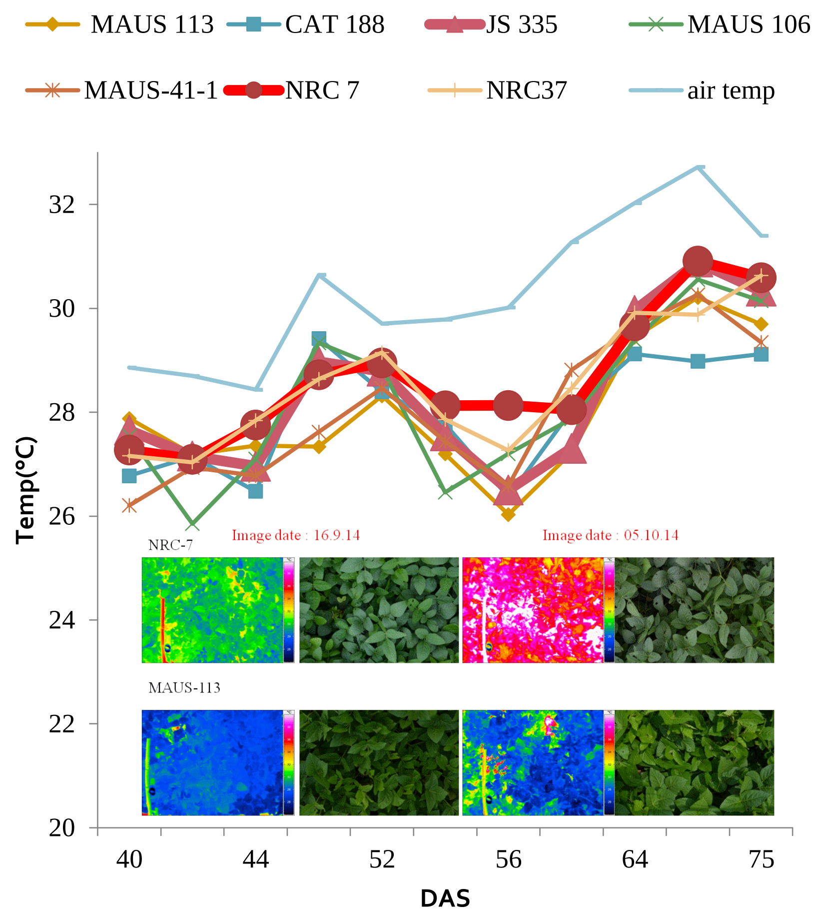
Water Soil Atmosphere

Excess or Deficit; Low or high

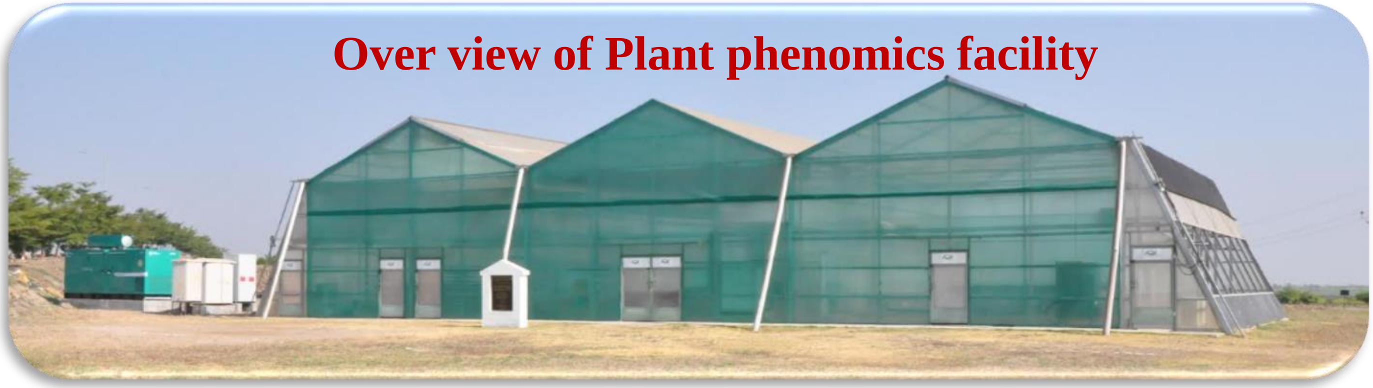
http://www.niam.res.in

Canopy temperature throughout crop season can be monitored





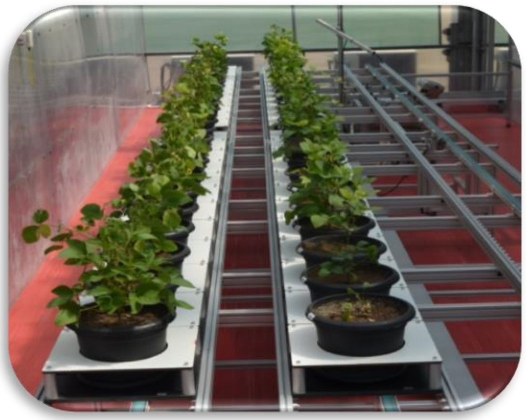
Plant Phenomics facility: Technology to closely moinitor plant responses in large scale



Over view of Plant phenomics facility

Growth Chamber 1

Imaging Chamber

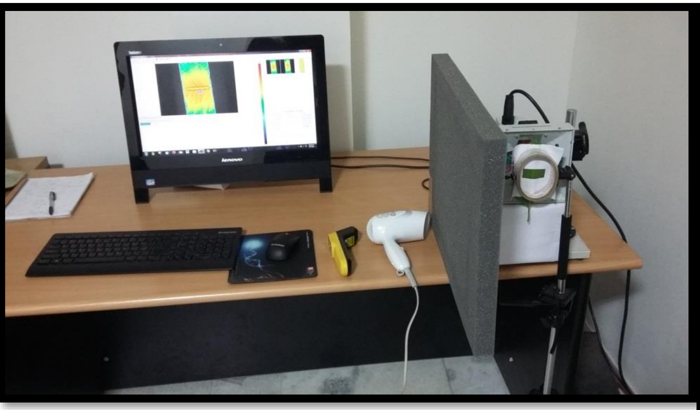


Growth Chamber 2

09:14:47

Server

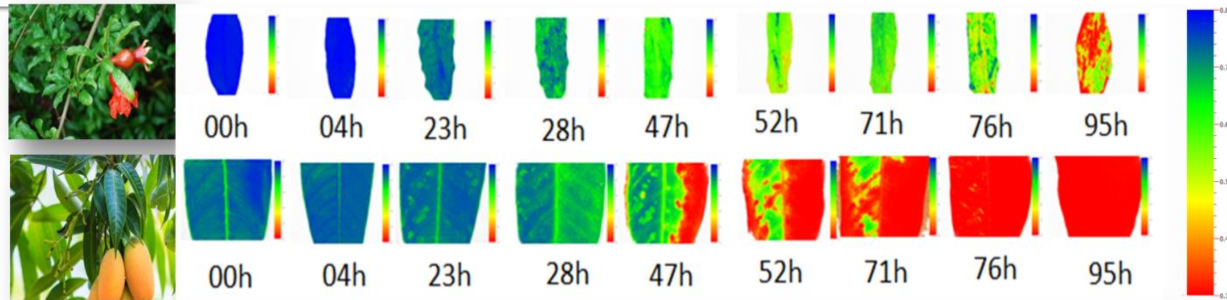
Photosystem sensitivity: Dryland fruit crops

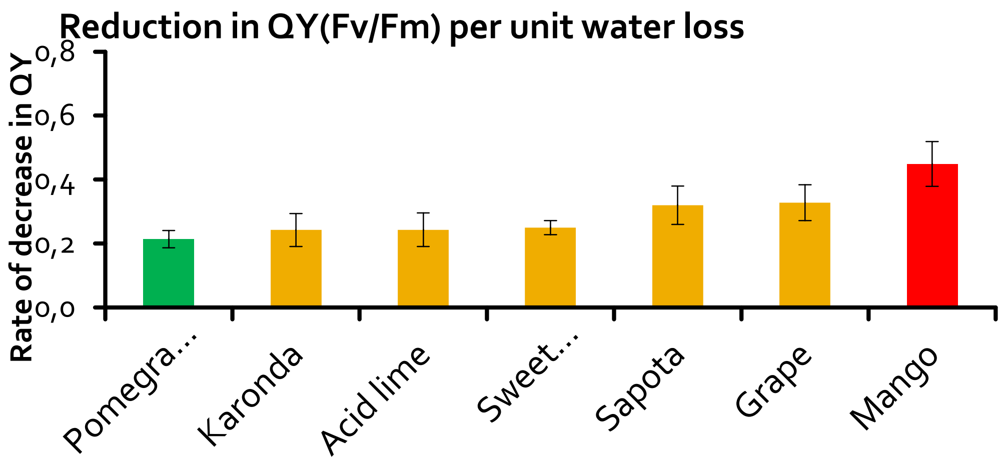


CHLOROPHYLL FLUORESENCE IMAGING

- 11 orchard crops
  - Acid lime
  - Draggon fruit
  - Guava
  - Karonda
  - Mango
  - Sapota
  - Sweet orange
  - Pomegranate
  - Custard Apple
  - Jamun
  - Grape
- 5 replications of each crop

Investigation on photosynthetic efficiency of Horticulture crops during descication





Tools and methods developed can help identify effect of bioregulators/ biostimulants on physiology of plants

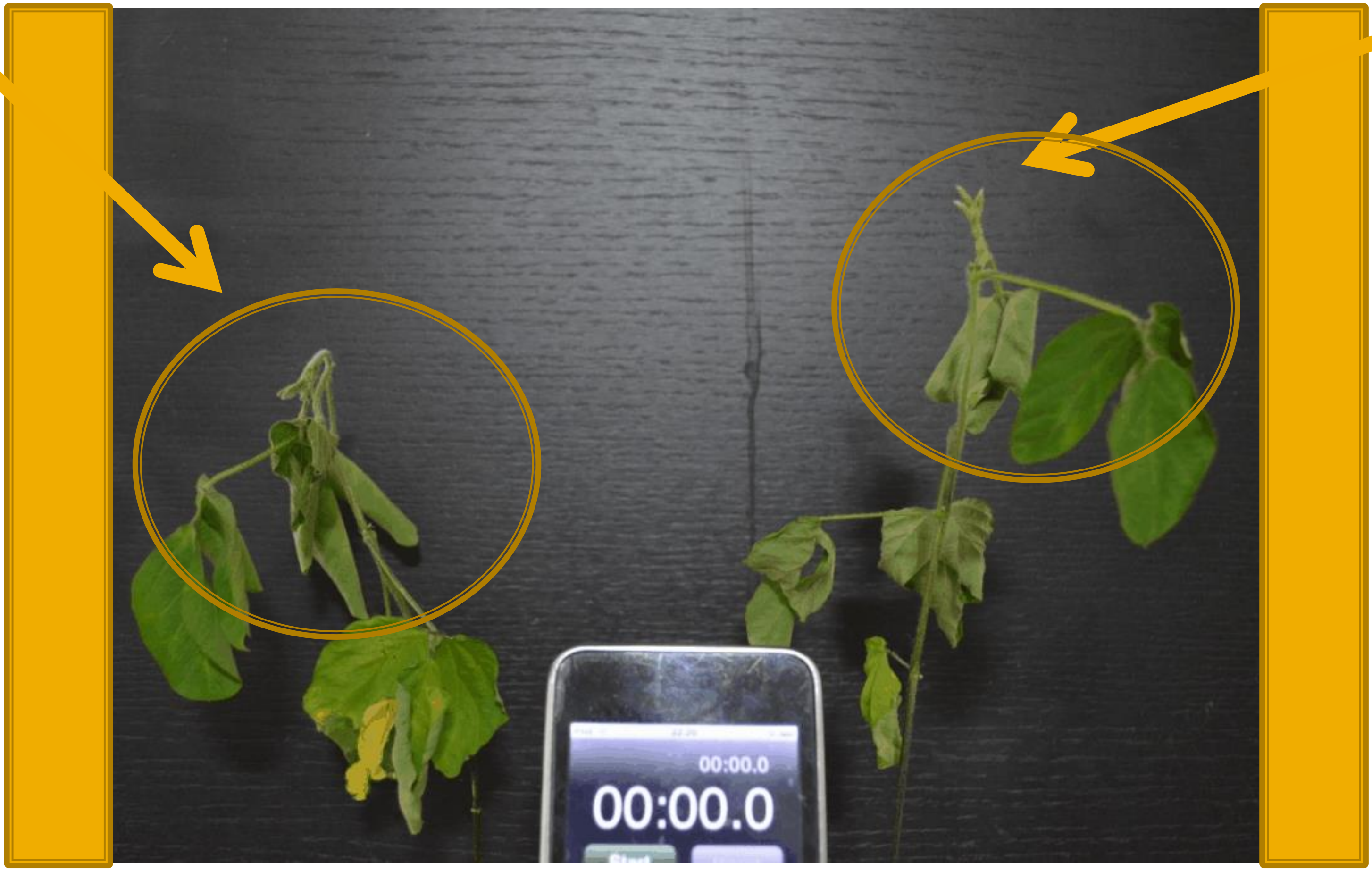
Develop/optimise tools to scale up phenotyping capacity

Imaging Scientific Hints About Resilience to Abiotic Stress

(ISHARAS)

- Image capture
- Image analysis
- Database and Inference

Image based tools can expand our knowledge for crop management decision



Future perspectives

- Can we use phenomics to identifiy
  - right combination of crop genotype and management practice ??
- Can bioregulators and biostimulants
  - be part of smart resource management
  - Survival of seedlings to protection of pollen grains to avoid sterility-flower droop-fruit drop
  - Improved recovery from temperature and drought stress

Summary

- Definition of climate smart agriculture should encompass abiotic stress tolerance, in season stress management
- Available hints useful for translating power of science into product
  - Resilient crop genotypes
  - Management for resilience
- Phenomics tools are emerging for high throughput can complement effort for the best management solutions
  - Effective bioregulators and time of application for greater profit for farmers

Acknowledgement

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- Director ICAR-NIASM
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- EWG Phenotyping Wheat
- My colleagues at
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  - ICAR NIASM

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