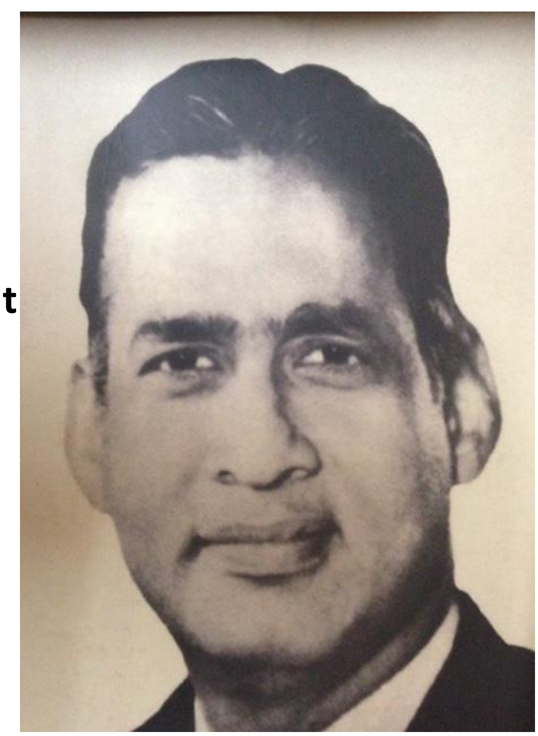
Prof Y Nayudamma Memorial Lecture

On
"Plant Adaptaions Combating Climate Change

P S Ahuja

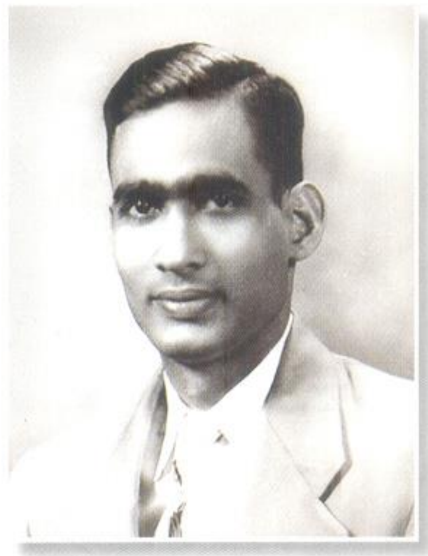
Yelavarthy Nayudamma 1922-1985

A legend in his lifetime who put Indian leather on the world map.



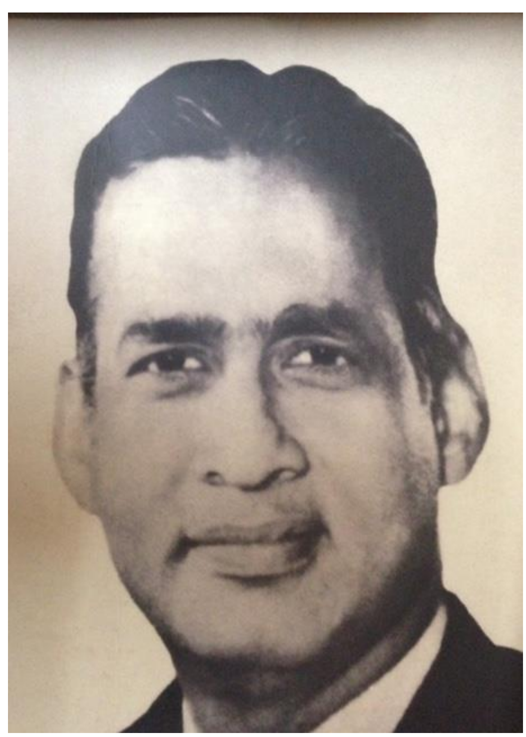
To Pandit Jawahar Lal Nehru

Nayudamma replied: I will endeavour to infuse scientific temper to the tradition-bound leather industry, being pursued by the socially and economically downtrodden leather artisans and help in their socio-economic uplift.? Nehru was impressed with that reply and Nayudamma was confirmed as the Director.

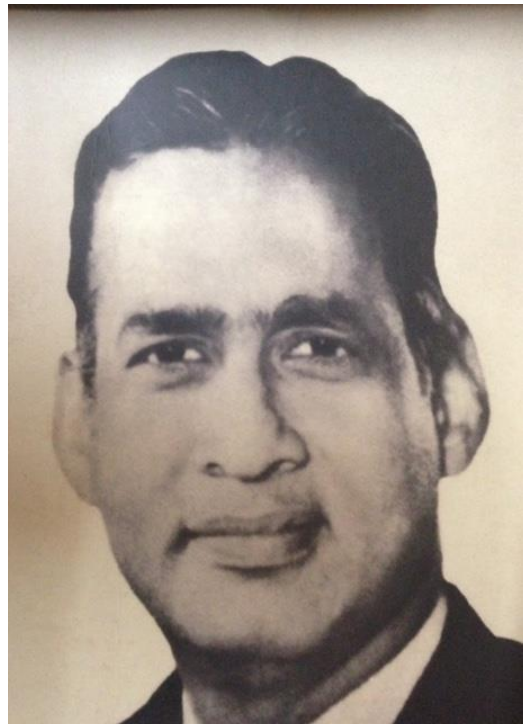


Dr Y Nayudamma
Youngest Director, CLRI
1956-1973

- ✓ His important contribution was the innovation in fat liquors required to soften leathers.
- ✓ Development of acrylic resin emulsions for use in leather finishing.
- ✓ He also made several important contributions to the development of new and improved processes for the manufacture of leathers.
- ✓ He authored an ACS Monograph " Education in Leather Technology."

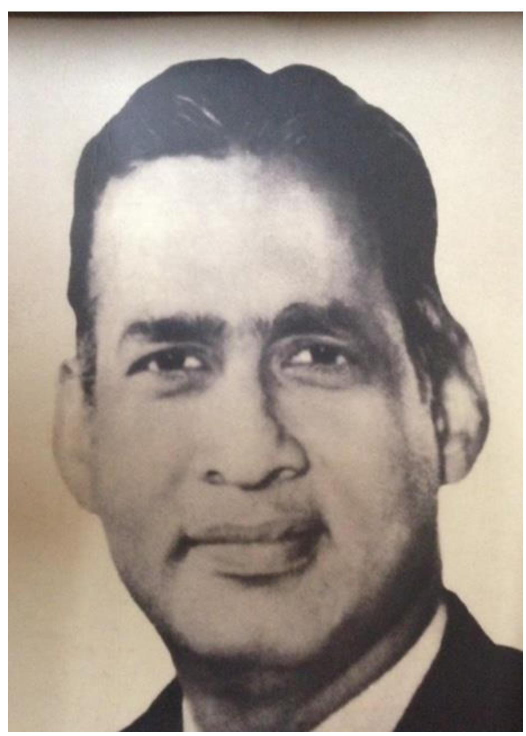


- ✓ Studies on the physico-chemical properties of raw and tanned collagen coordination complexes of chromium, aluminum and zirconium combination tannages such as chrome-vegetable tanning biogenesis and chemistry of vegetable tannings mechanism of tanning, in particular protein-tanning interactions.



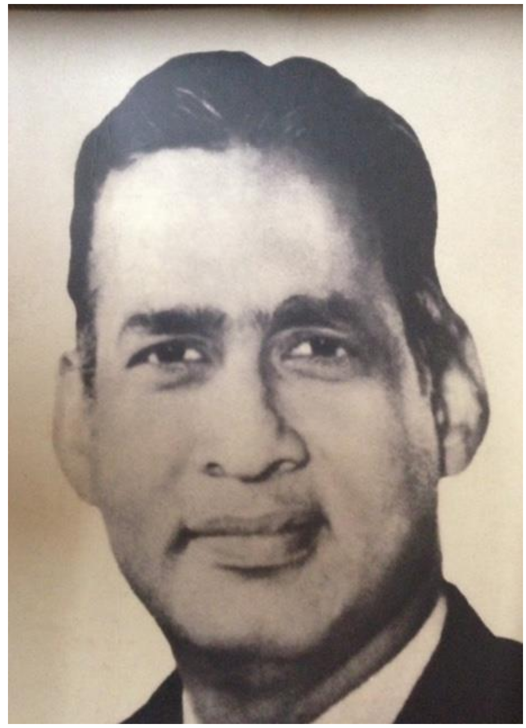
Dr Nayudamma Linked the products of CLRI with the life of the people he strove to serve. He built a societal contract to his research and development activities

Dr T. Ramasami
Secretary
Dept. of Science and Technology Govt. of India

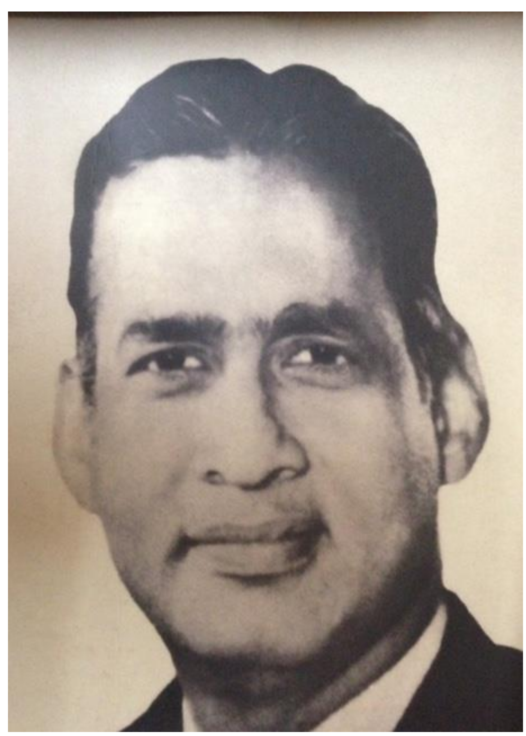


"His width of understanding and depth of knowledge of human society, science and technology were most needed at the time he took over as the Director General, as CSIR had gone through a very difficult period of five years preceding his term"

H.A. Parpia



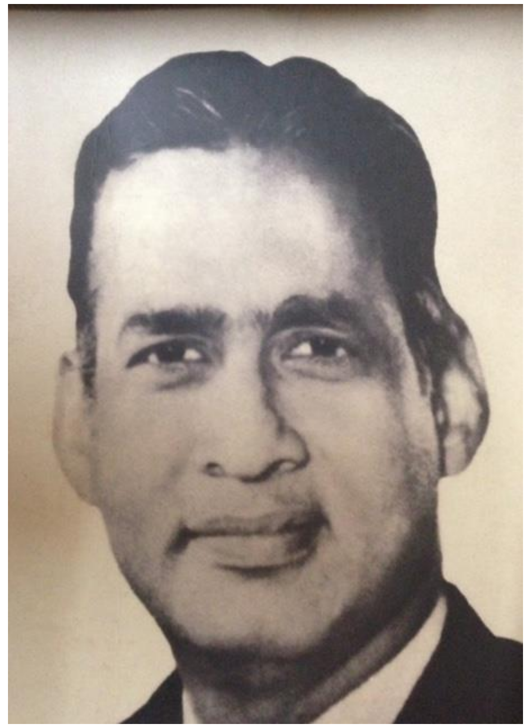
He was of the opinion that CSIR laboratories should have a strong tecnology focus for industrial and societal development and wealth generation and that the laboratories need to generate the salaries of the staff



The Karim Nagar Experiment

Nayudamma
Was amongst the first to step in and help in Integrated Rural Development

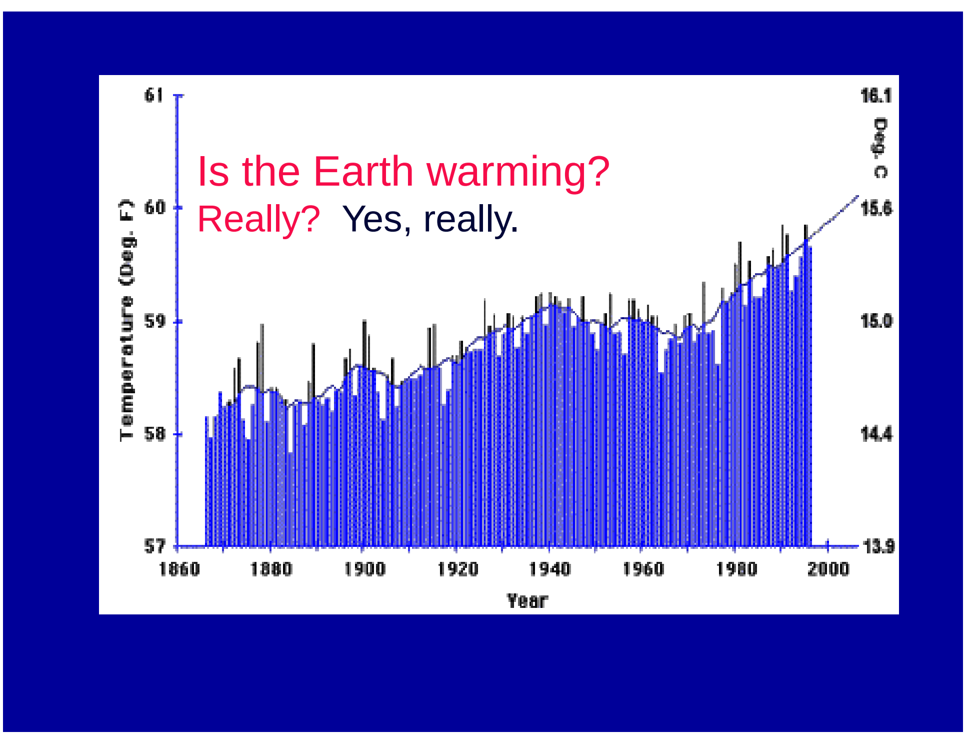
Dr Manmohan Singh
Prime Minister of India



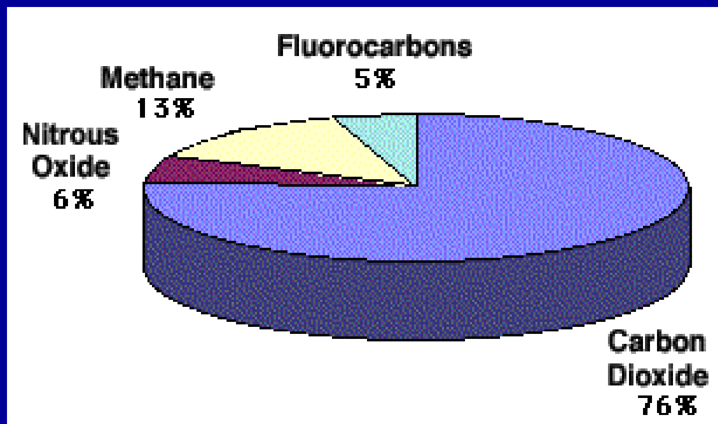
Dr Nayudamma was the Vice Chancellor of Jawahar Lal Nehru University, a Distinguished Scientist and a member on the Board of IDRC

I am privileged to get this opportunity to deliver the Prof Y Nayudamma Memorial Lecture

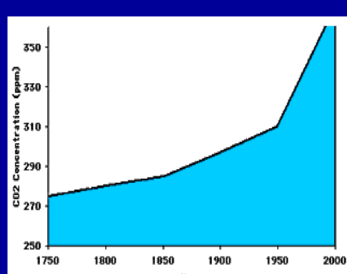
On
"Plant Adaptaions Combating Climate Change

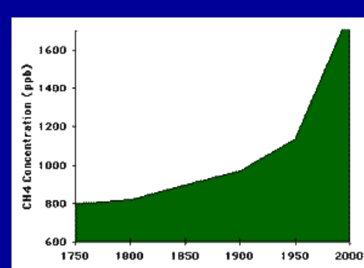


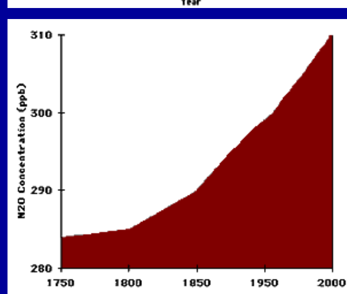
Four Major Greenhouse Gases

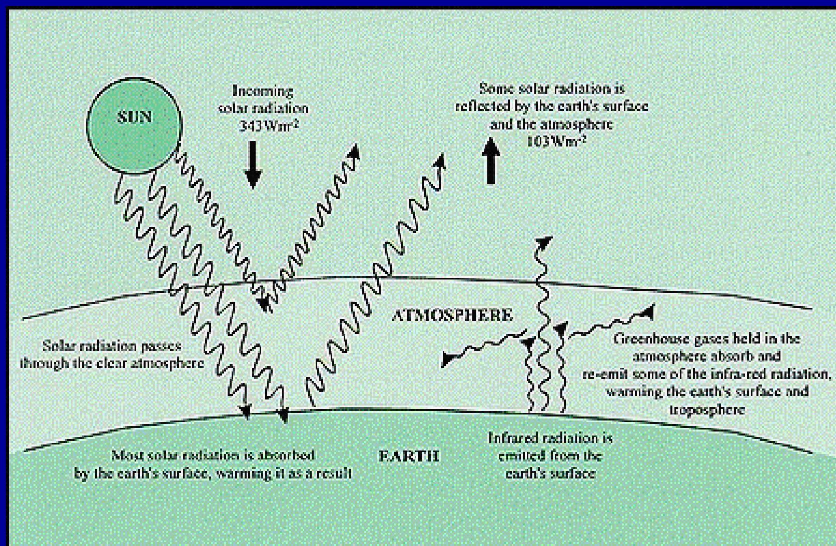


Greenhouse gases on the Rise





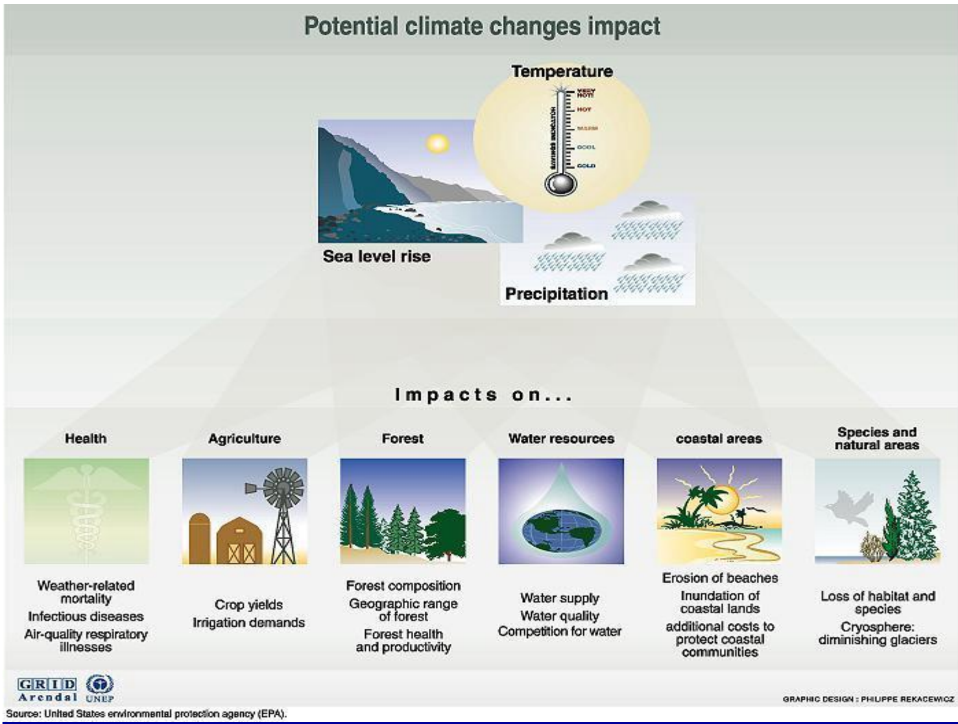


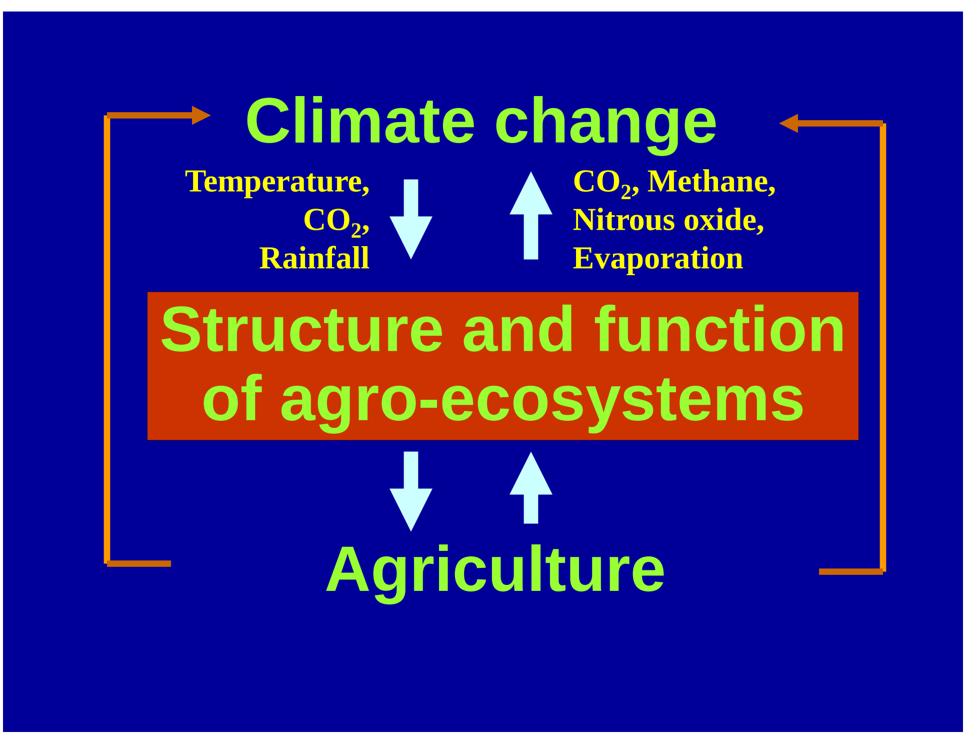


Greenhouse effect

The main questions are:

1. Is the earth really warming up?
2. How is it happening?
3. Whether agriculture contributes towards the global warming?
4. If yes, how?
5. What will be impacts of global warming on agriculture?
6. What can be done to reduce the global warming and adapt to the climate change?


Potential climate changes impact
Temperature
Sea level rise
Precipitation
Impacts on...
Health
Agriculture
Forest
Water resources
coastal areas
Species and natural areas
Weather-related mortality
Infectious diseases
Air-quality respiratory illnesses
Crop yields
Irrigation demands
Forest composition
Geographic range of forest
Forest health and productivity
Water supply
Water quality
Competition for water
Erosion of beaches
Inundation of coastal lands
additional costs to protect coastal communities
Loss of habitat and species
Cryosphere: diminishing glaciers
GRID Arendal
UNEP
GRAPHIC DESIGN : PHILIPPE REKACEWICZ
Source: United States environmental protection agency (EPA).


Climate change
Temperature, CO2, Rainfall
CO2, Methane, Nitrous oxide, Evaporation
Structure and function of agro-ecosystems
Agriculture

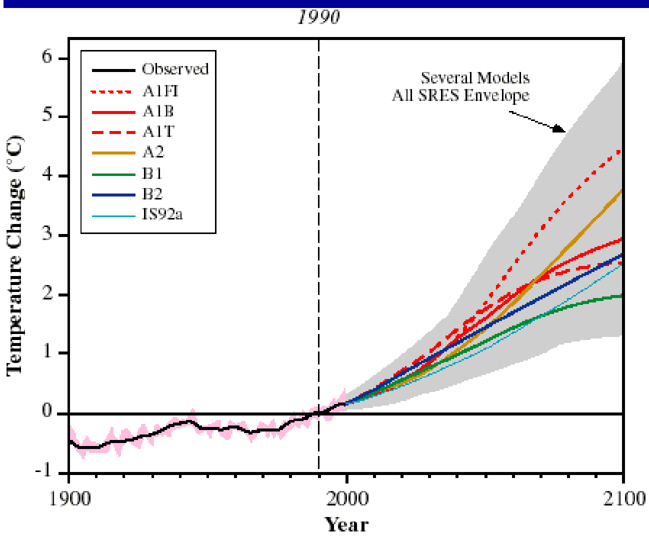
Impact of climate change on agriculture

Estimates of Future Levels of CO_2

Year	CO_2, ppm
2000	369
2010-2015	388-398
2050/2060	463-623
2100	478-1099

Source: IPCC, 2001

Projected rise in surface temperature



Source:
IPCC 2001

Policy Decisions

Implementation of mitigation strategies require decisions at many different levels

- **International (International Organizations)**
- **National (National Government)**
- **Local (Local bodies)**
- **Field (Farmer)**

At National Government level

- Land use should be determined by *Climate Policy* along with Agriculture Policy
- Public education program to help advance adoption
- Crop insurance to share the risk of failure
- Providing subsidy to popularize mitigation measures

A system of incentives and regulations will be needed to secure participation in the implementation programme

Farmers' level

Some technologies provide "win-win" possibilities asserting that the farmer would make money, lower emission and have positive environmental externalities. Some of the strategies are:

- Switching to a different land-use pattern
- New cultivars
- New agri-management

International level:

Kyoto Protocol establishes country specific emission reduction targets

Driving forces

- Markets for Emission Trading
- Trading across gases based on their Global Warming Potential (GWP)
- Trading across countries: emission trades, joint implementation, Clean Development Mechanism

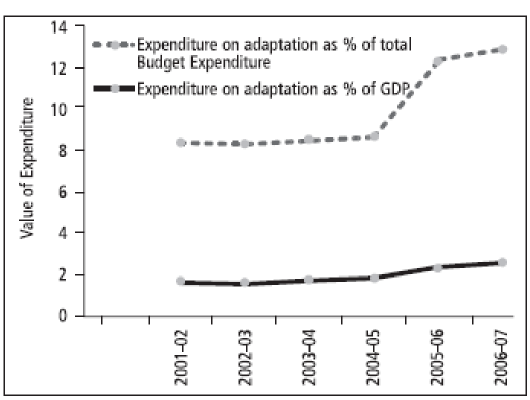
Mitigation related programmes

INDIA'S POLICY STRUCTURE RELEVANT TO GHG MITIGATION

- Promotion of energy efficiency in all sectors
- Emphasis on mass transport
- Emphasis on renewables including biofuels plantations
- Accelerated development of nuclear and hydropower for clean energy
- Focused R&D on several clean energy related technologies

Actions for Adaptation and Mitigation

Adaptation, in the context of climate change, comprises the measures taken to minimize the adverse impacts of climate change, e.g. relocating the communities living close to the sea shore.



Current government expenditure on adaptation to climate variability exceeds 2.6% of the GDP

Adaptation related programmes

- **CROP IMPROVEMENT**
- **DROUGHT PROOFING**
- **FORESTRY**
  – an aggressive afforestation and sustainable forest management programme resulted in annual reforestation of 1.78 mha during 1985-1997, and is currently 1.1 mha annually.

  – Due to this, the carbon stocks in Indian forests have increased over the last 20 years to 9 -10 gigatons of carbon (GtC) during 1986 to 2005.

Impacts of Climate Change - Observed

- *Growing Season*: Lengthened by 1 to 4 days per decade during the last 40 years
- *Plant Animal Ranges*: Shift pole-ward and up in elevation for plants, insects, birds, fishes etc.
- *Breeding, Flowering and Migration*: Earlier plant flowering, bird arrival, breeding season

CHANGES IN CLIMATE HAVE ALREADY BEGUN TO AFFECT BIODIVERSITY

Impacts on Mountain Ecosystems in India – Western Ghats & the Nilgiris

Nilgiris

- Increase in area under evergreen forests
  - increased precipitation
- Increase in dry thorn forest
  - increased temperature

Uttara Kannada

- Shift from drier to moister vegetation types

Rate of change of climate faster than capacity of ecosystems and plant species to adapt

Why Adaptation?

- Threat to unique ecosystems and biodiversity, rendering several species extinct, locally and globally
- Adversely affect GDP, food production, timber production, markets, trade and prices
- Developing countries are more vulnerable to climate change than the industrialized countries
  - unmanaged, or poorly managed systems of food production, fisheries, coastal protection, forest management, deforestation
- Poorly developed institutions, markets, technology transfer pathways and lack of financial resources in developing countries

Why Adaptation…

- Increase in the frequency and intensity of extreme events would adversely affect all sectors and regions
- Long gestation periods for developing and implementing adaptation strategies
- Lack of awareness among different stakeholders because of inadequate access to information
- Inertia in climate and ecological systems, & socio-economic systems

Direct impacts of climate change (long-term)

- **Production of kharif crops may not be affected but may become more risky due to increased climatic variability and pest incidence.**
- **Production of rabi crops is more seriously threatened due to large increase in temperatures and higher uncertainties in rainfall.**

Strengthening the Climate change research

- What is the nature and extent of climate
- What is the impact on agriculture?
- How land-use has changed over time?
- What are the adaptation strategies in terms of land-use change?
- Comprehensive model-based analyses and improved databases on soils, land-use and greenhouse gas fluxes.
- Developing new varieties. Genetically engineered plants may have good potential.
- Improving assessment of mitigation options.

Adaptation Strategies

- **Reactive**
  - responses that institutions, individuals, plants and animal communities are likely to make after the impacts of climate change have been observed
- **Autonomous**
  - natural or spontaneous adjustments in the face of changing climate
- **Anticipatory adaptation**
  - deliberate decisions made, based on foresight and planning, to prepare for the potential effects of climate change
- **Planned**
  - conscious interventions

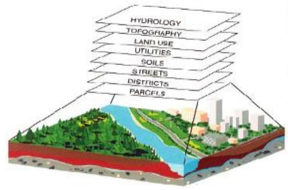
Strategy for the Future

1. Modeling: Regional climate projections
2. Vegetation response models:
   - Validate existing models
   - Adapt vegetation models for complex forest types
   - Incorporate socio-economic interactions
3. Database generation
   - Forest inventory
   - Plant physiological functions
   - Socio-economic pressures

Strategy…

4. Creating awareness in forest department, researchers, policy makers
5. Incorporate climate considerations in forest management
   - Working plans and microplans
6. Institution and capacity building
   - Research team, sustained research
7. Adopt "*no regret*" measures
   - Forest conservation, prevent fragmentation, mixed species forestry etc.

Facilities for Climate Change Research



RS-GIS Set up

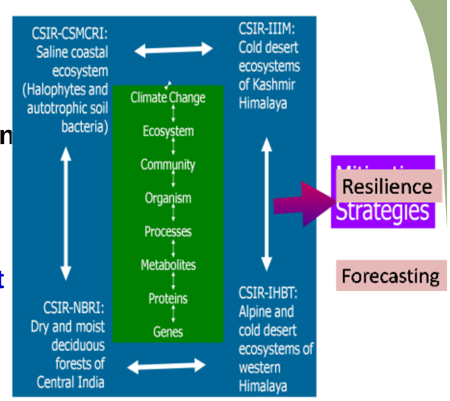
Environmental data station

FACE and FATI Installation

CSIR - IHBT

Exploratory studies on climate change and adaptation of species complexes

1. Time series analysis (change detection studies) of natural vegetation in distinct bio-geographical regions using RS/ GIS techniques
2. Changes in population dynamics and phenology in plant species in different ecosystems under native and FACE/FATI environment (simulated scenario).



3. Developmental biology of key/ vulnerable species at high altitudes and in trans Himalayas
4. Effect of CO2, temperature and other climatic factors on primary and secondary metabolism under native and CO_2 enrichment (FACE)/ temperature increase (FATI) environment.
5. Transcriptome dynamics and utilization of genes for plant adaptation under climate change

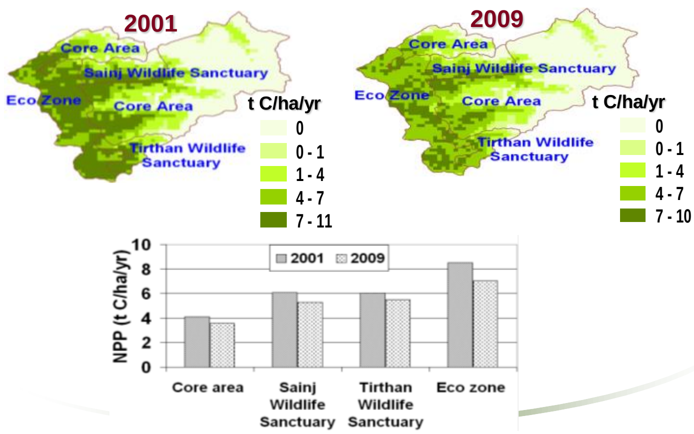
CSIR - IHBT

Time series analysis of natural vegetation using RS/ GIS techniques

Missing Long Term Ecological Research (LTERs) in protected areas: a must for such studies" collaborated with Forest Dept.

Institute	LTER	Ecosystem
CSIR-IHBT	10	**Western Himalaya (mid & high altitude)**

GHNP



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Changes in Population dynamics and phenology in plant species in different ecosystems under native and FACE/FATI environment

- Developed baseline data on biodiversity assessment, community analysis and environmental data for various ecosystem. These are critical to assess species recruitment and migration.

•313 higher plant species belonging to 204 genera and 68 families from Rupi Bhabha valley

•237 species were encountered and recorded from the forests of the Bilaspur Division

CSIR - IHBT

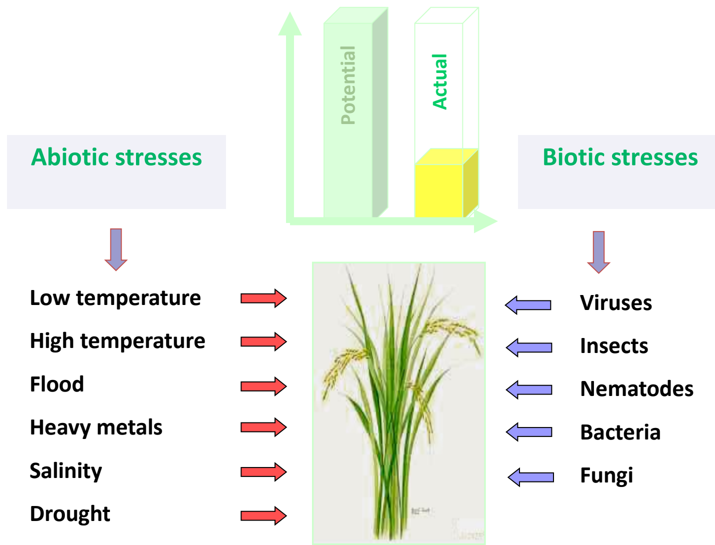
CSIR - IHBT

Impact of Climate Change on Plant Distribution

- in Alps grassland species have crept up by 4m/decade
- in Europe, upward shift of 171 plant has been reported
- In Himalaya: spatial redistribution of species (*Soliva anthemifolia)*
- Apple cultivation has shifted to higher altitudes in Lahaul-Spiti
- Many of the world's poorest people rely on medicinal plants not only as their primary healthcare option, but also as a significant source of income. The potential loss of MAP species from effects of climate change is likely to have major ramifications on the livelihoods of large numbers of vulnerable populations across the world

CSIR - IHBT

Stresses affect yield



Adaptation Biology

- **Identifying relevant processes for imparting stress tolerance**
- **Developing indigenous gene resources, including promoters and their validation**

Gene Discovery :

Genomic approaches and

candidate gene approach

Response to stress

Stress (Drought, Temperature, Salinity)

↓

Disruption of osmotic and ionic homeostasis;
damage of functional and structural proteins and membranes

↓

Signal sensing Perception, transduction

Osmosensors (AtHK1), phospholipid-cleaving enzymes (PLD), second messengers (Ca2+, PtdOH, ROS), MAP kinases, Ca2+ sensors (SOS3), calcium-dependent protein kinases (CDPKs)

↓

Transcription factors (e.g. CBF/DREB)

Transcription control

↓

Stress-responsive mechanisms

Gene activation

- Chaperone functions (Hsp, SP1, LEA, COR)
- Detoxification (SOD, PX)
- Osmoprotection (proline, GlyBet)
- Water, ion movement (aquaporin)

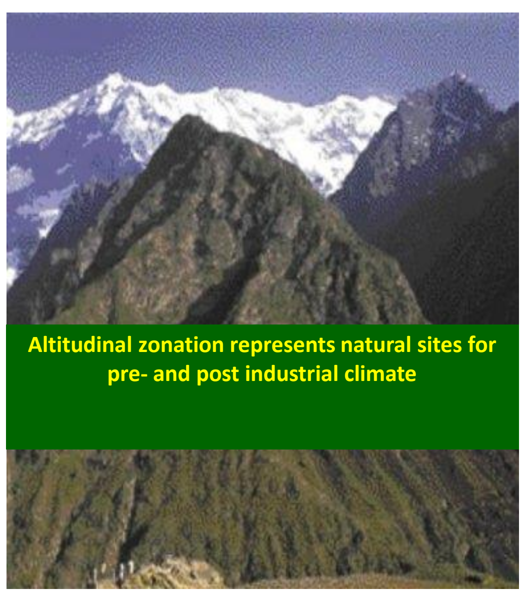
↓

Re-establishment of cellular homeostasis, functional and structural protection of proteins and membranes

↓

Plant response to stress

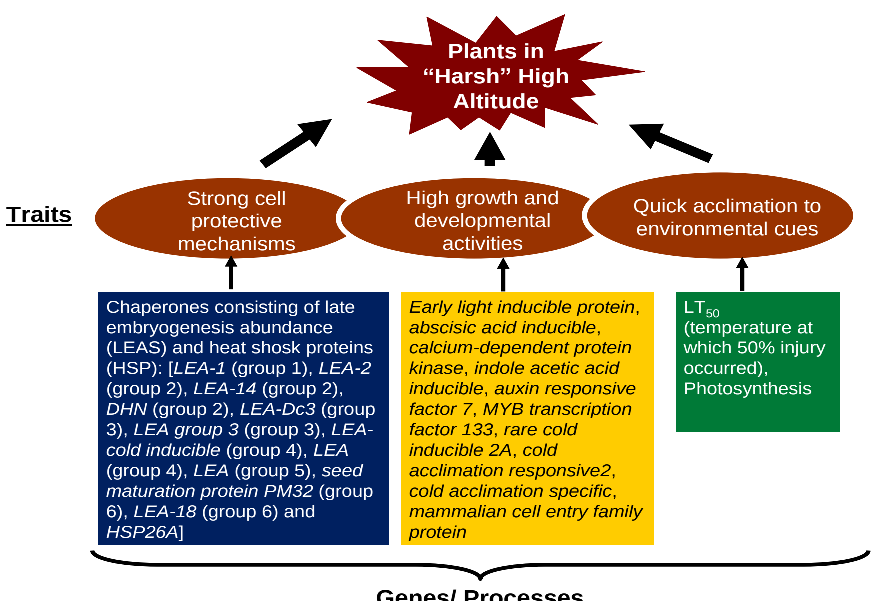
Low temperature
Low CO_2
Pre-industrial



High temperature
High CO_2
Industrial

IHBT

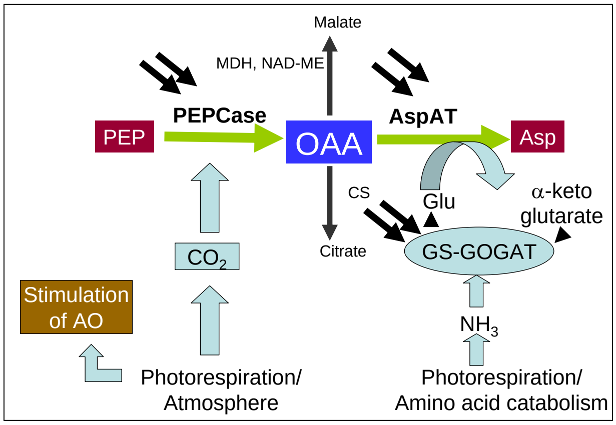
Three major traits for plant thriving at high altitude ------



Bhardawaj et al., 2013

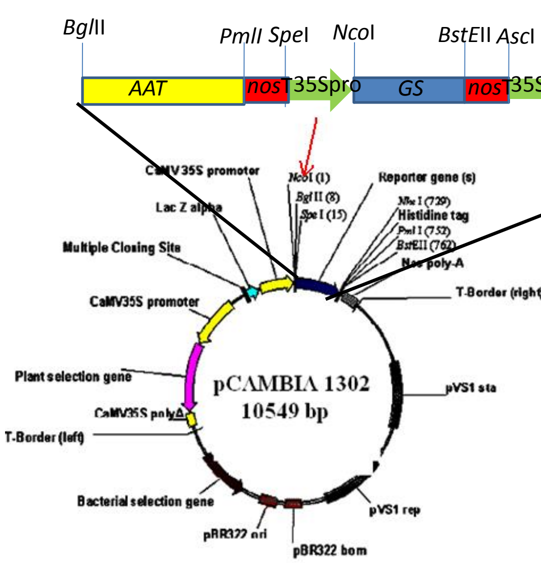
Carbon fixation at high altitude: a novel strategy

[Photosynth Res: 88: 63-71 (2006); J Plant Physiol. *164: 31-38* (2008)]



Adopted as part of the **course on Forest Ecology** of the **University of Minnesota, USA** (https://wiki.umn.edu/FR_3104_5104/PhotoSynthesis) on **photosynthesis**

Pathway transplanting for efficient carbon capture

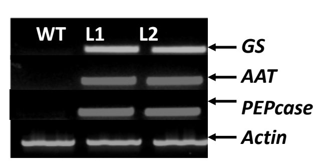


pro*GS *ter **cloned in to** ***Spe*I and *Pml*I**

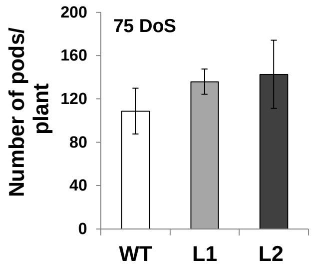
AAT ter **cloned in to** ***Bgl*II and *Spe*I**

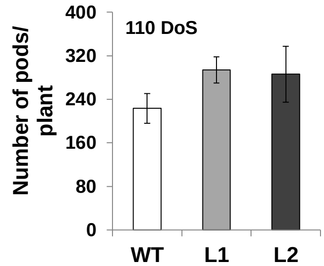
AAT is using the 35S promoter of the pCAMBIA 1302

***pro*PEPCase** **cloned in to** ***Asc*I and *BbvC*I**



Transplanted the pathway: Transgenics had higher yield, better C and N

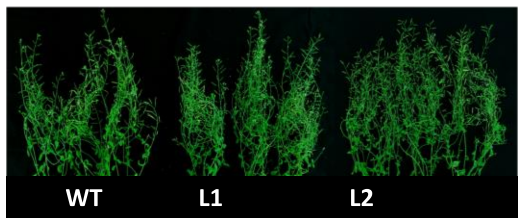




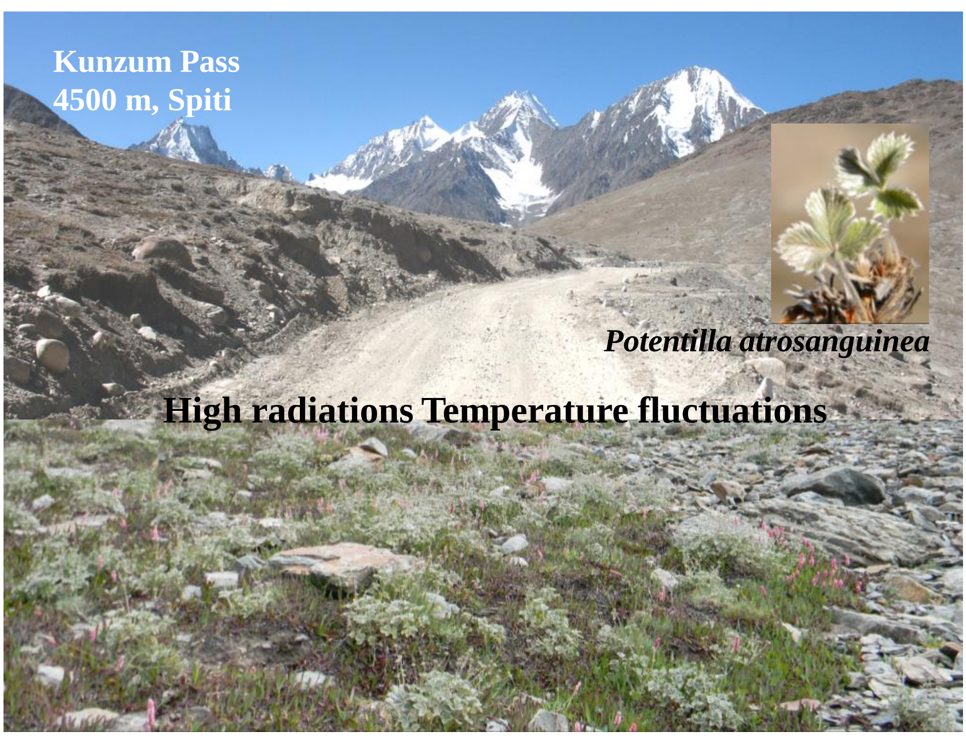
100 seed weight

WT: 1.92 mg

TL: 1.99 mg

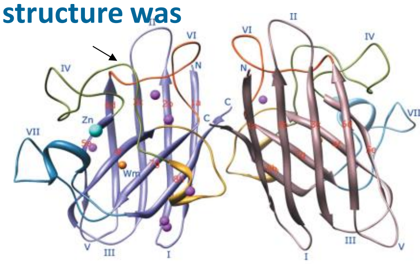


IHBT



Identified a novel superoxide dismutase from high altitude and also the Crystal structure was deciphered

A dimer consisting of subunits A and B.

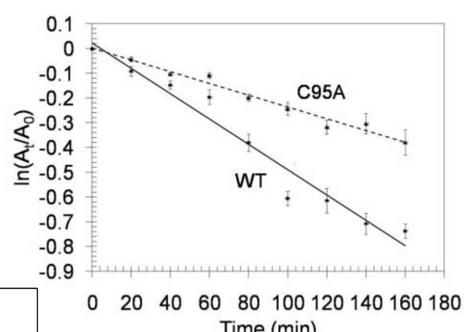


	Pa-SOD	So-SOD
Interface accessible surface area		
Interface ASA (Å^2)	626.0	714.35
Interface ASA (%)	8.56	9.34
Polar atoms (%)	25.0	28.4
Nonpolar atoms (%)	74.9	71.5
Gap volume	2688.6	4251.5

Enzyme tolerates autoclaving and functions from sub-zero to >40°C

Acta Cryst. Sec D Biological Cryst. D64, 892–901; 2008
US Patents 6,485,950; 2002
US Patents 7,037,697; 2006; 1031del 2011

Cysteine modification improves thermostability

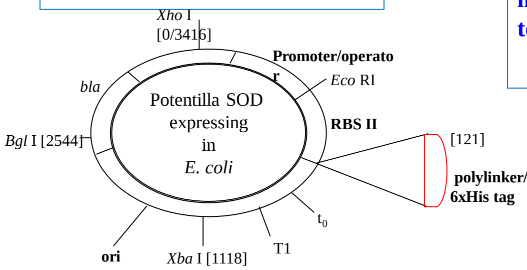


Enzyme	k_d (min^{-1})	$t_{1/2}$ (min)
WT	4.6 ± 0.18 × 10^{-3}	151 ± 6
C95A	2.4 ± 0.31 × 10^{-3}	345 ± 36

The rate constant (*kd*)
(min^{-1}) and $t_{1/2}$ for first-order thermal inactivation

Plant Industry:
To raise transgenic plants tolerant to abiotic and biotic stresses

Food Industry:
To extend shelf life of Processed/ un-processed food items such as cooked/packed vegetables, chiken, meat and other items pertaining to the industry

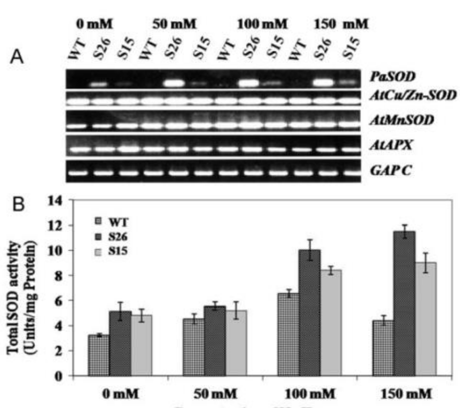


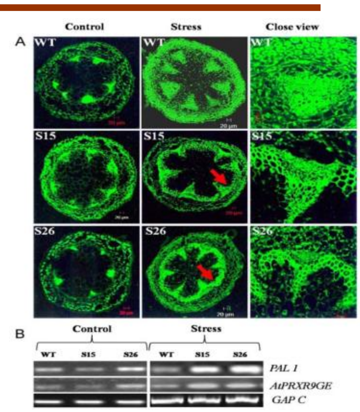
Pharmaceutical industry:
1. Extending the shelf life of organelles (cornea/lens)
2. Cryopreservation, cryosurgery
3. Organelle transplantation
4. Treatment of asthma, rheumatoid arthritis, Ageing related diseases

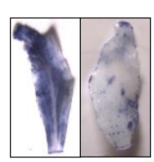
Cosmetic Industry:
To be included in cream, shampoo, lotion etc.

IMPLICATIONS OF SOD

Over-expression of *superoxide dismutase* exhibits lignification of vascular structures in *Arabidopsis thaliana*







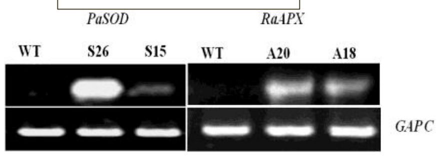
WT Transgenic

J Plant Physiol (2010), doi:10.1016/j.jplph.2009.12.004

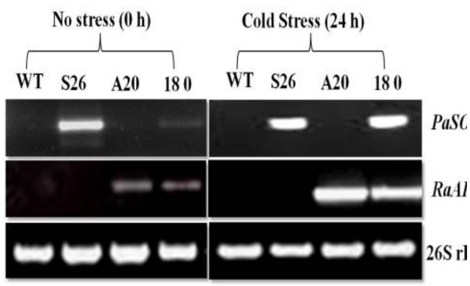
CSIR-IHBT

Evaluation of Transgene(s) Expression

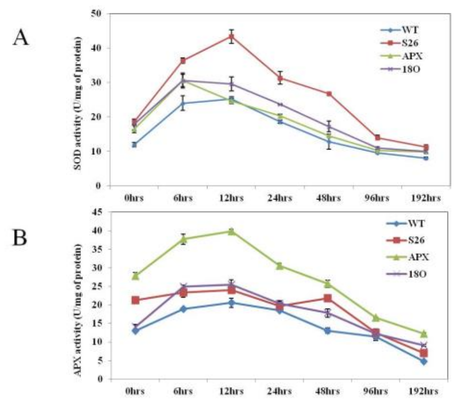
Genomic level



Transcription level

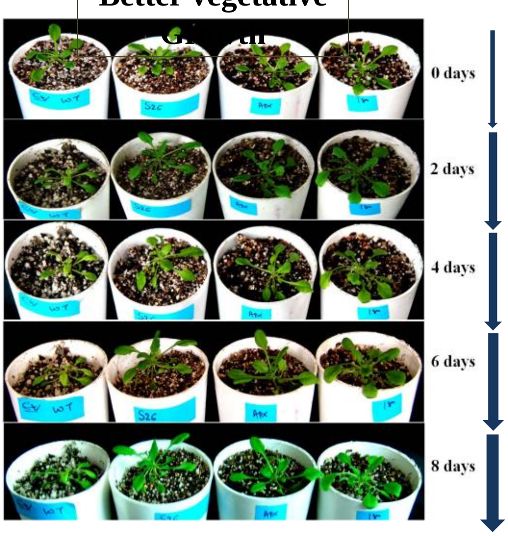


Proteomic level



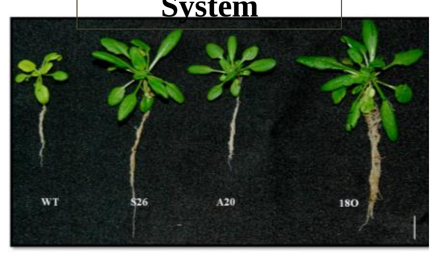
Transgenic plants exhibited better Growth

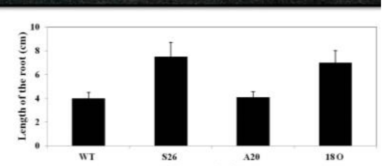
Better vegetative Growth



Cold Stress

Evolved Root System





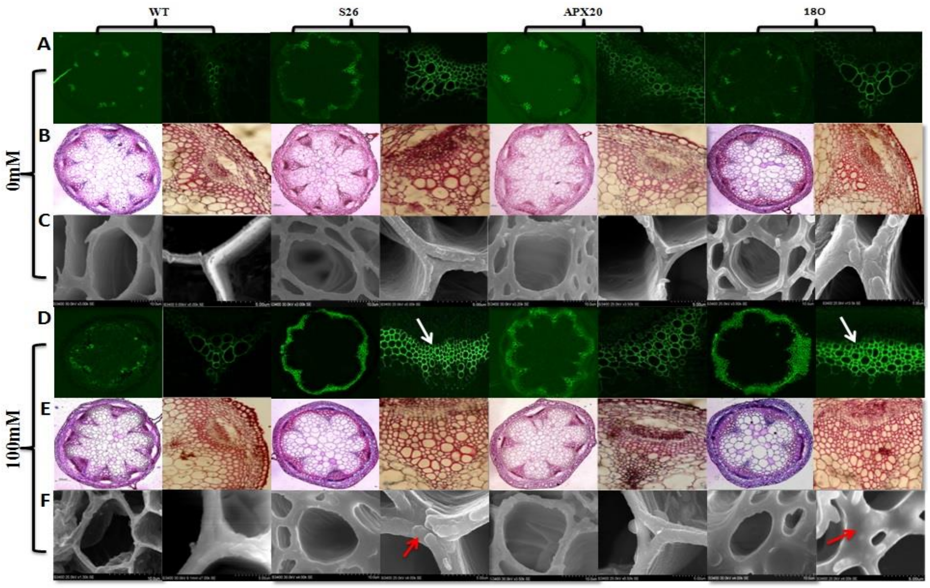
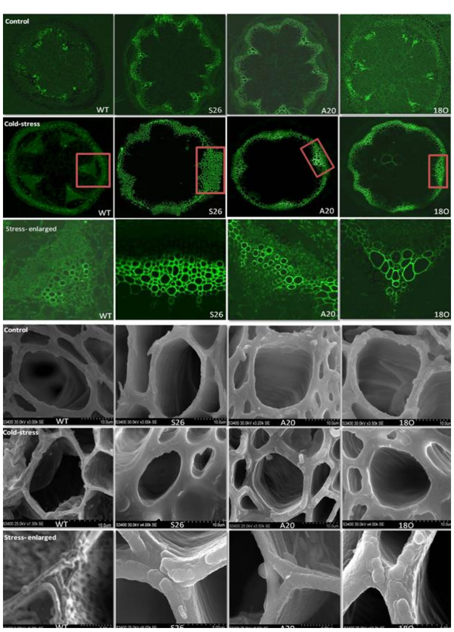
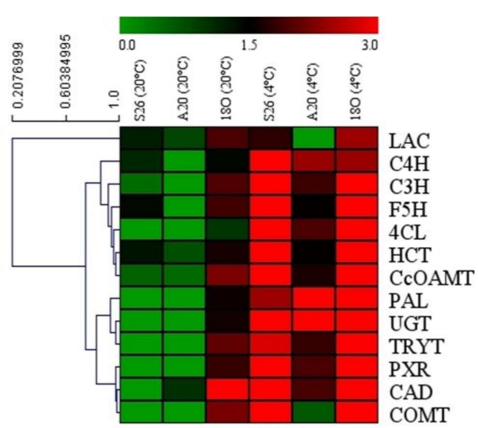


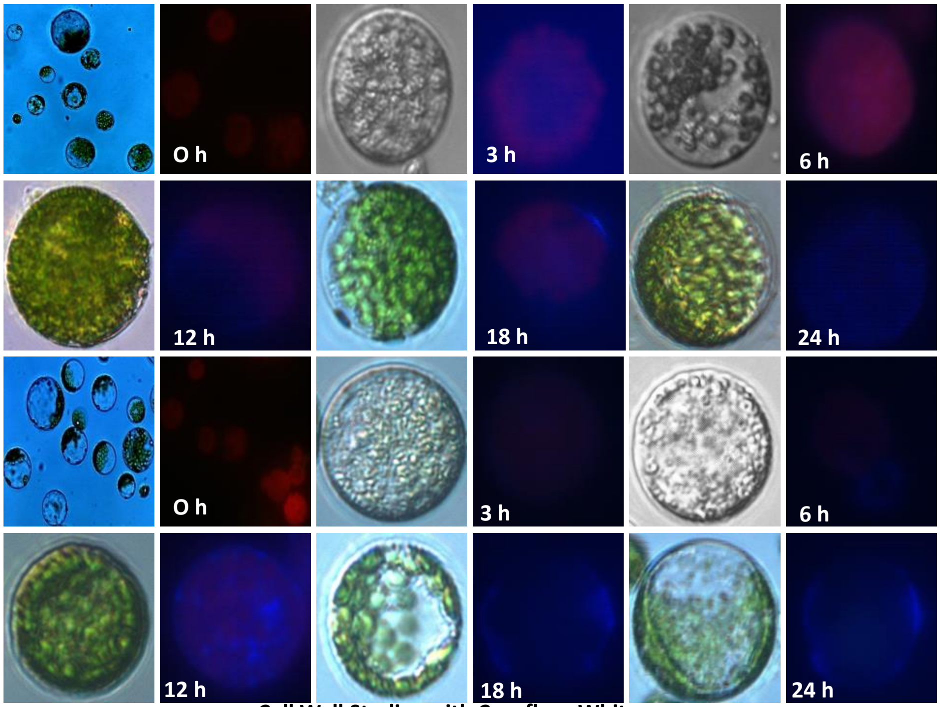
Figure 1: Histochemical Analysis of Lignin in the Inflorescence Stem of *Arabidopsis*

(A) and **(D)** Transverse stem sections of WT and transgenic lines (S26, APX20 and 18O) showing lignification pattern under control and salt stress (100mM). Close up view of the single vascular bundle of stress tissue is shown and white arrows show enhanced lignification in S26 and 18O line. Lignin autofluorescence was collected by excitation/emission wavelengths 488/505 nm by Confocal Laser Scanning Microscope.
(B) and **(E)** sections were stained for lignin with safranin-O. Lignin staining is red. Pictures were taken under a Bright-field microscope.
(C) and **(F)** sections observed under scanning electron microscope, Red arrows shows wall thickening in S26 and 18O line.

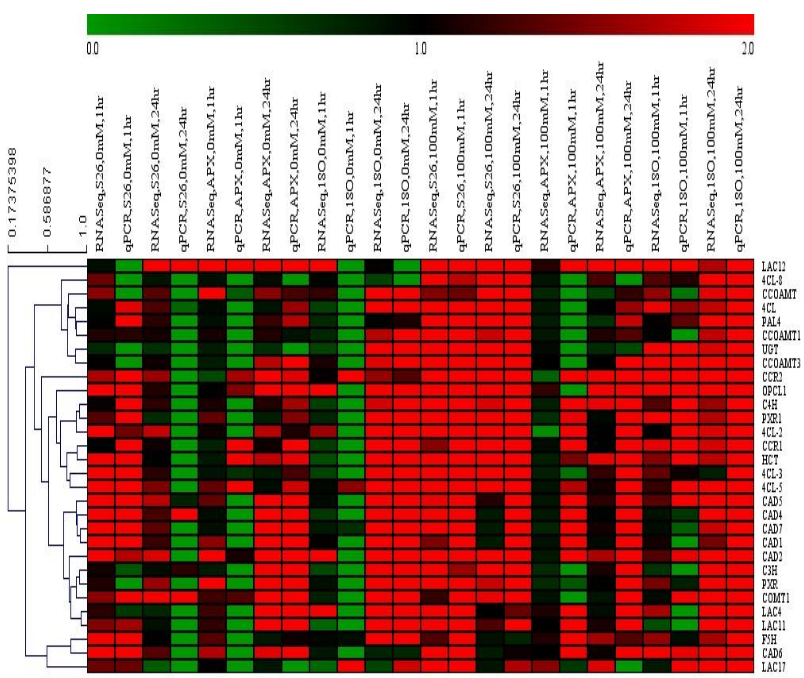
Lignin accumulation in Vascular tissues







Cell Wall Studies with Cacoflour White



Heatmap showing differential expression of lignin biosynthesis genes between control (0 mM) and stress (100 mM) salt treatments. Each square represents the average value of normalized peak intensities obtained from three biological replicates ranging from high (red) to average (black) to low (red) levels.

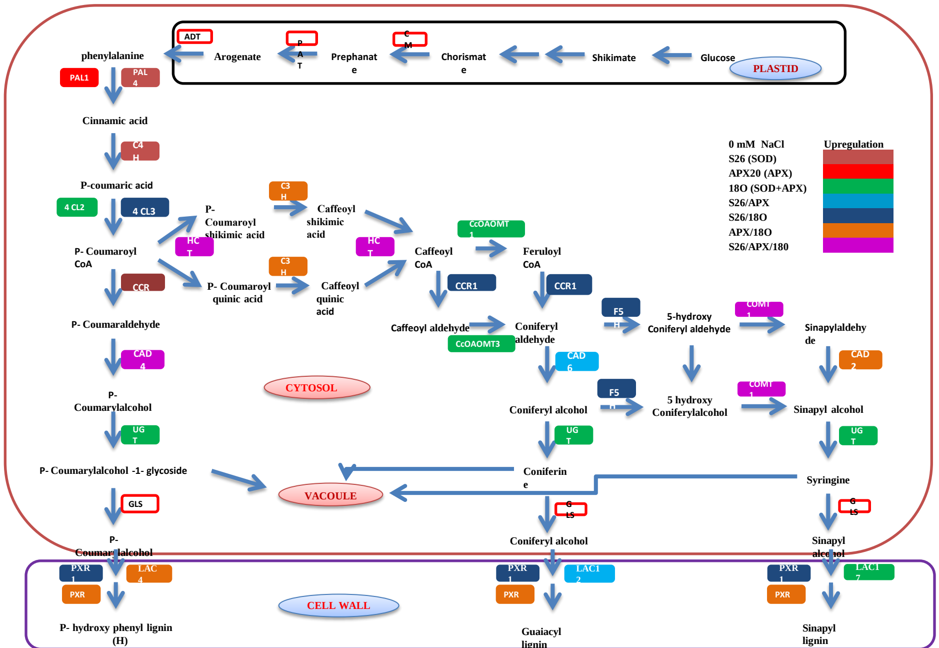


Figure 1. Diagram of the Monolignol biosynthesis upregulation in S26, APX20 and 18O under control (0 mM) conditions in comparison to WT.
The "metabolic grid" shown in this scheme incorporates the results of the studies done through RNA-seq and qPCR. Each arrow shows a reaction in the pathway, and next to each arrow is the name of the enzyme that catalyzes the associated reaction , Abbreviations are listed as per pathway. CM, chorismate mutase; PAT, prephenate aminotransferase; AGT, arogenate dehydratase; PAL, phenylalanine ammonia lyase; C4H, cinnamate 4-hydroxylase ;4CL, coumarate:CoA ligase ; CCR, cinnamoyl-CoA reductase; CAD, cinnamyl alcohol dehydrogenase ; HCT, hydroxycinnamoyl-CoA transferase ;C3H, *p*-coumarate 3-hydroxylase; F5H, ferulate 5-hydroxylase ; COMT, caffeic acid *O*-methyltransferase ; UGT, UDP-glucosyltransferase; LAC, laccases; PXR, peroxidases; CCoAOMT, caffeoyl-CoA 3-O-methyltransferase; H lignin, p-hydroxy phenyl lignin; G lignin, guaiacyl lignin monomers; S lignin, syringyl lignin monomers.

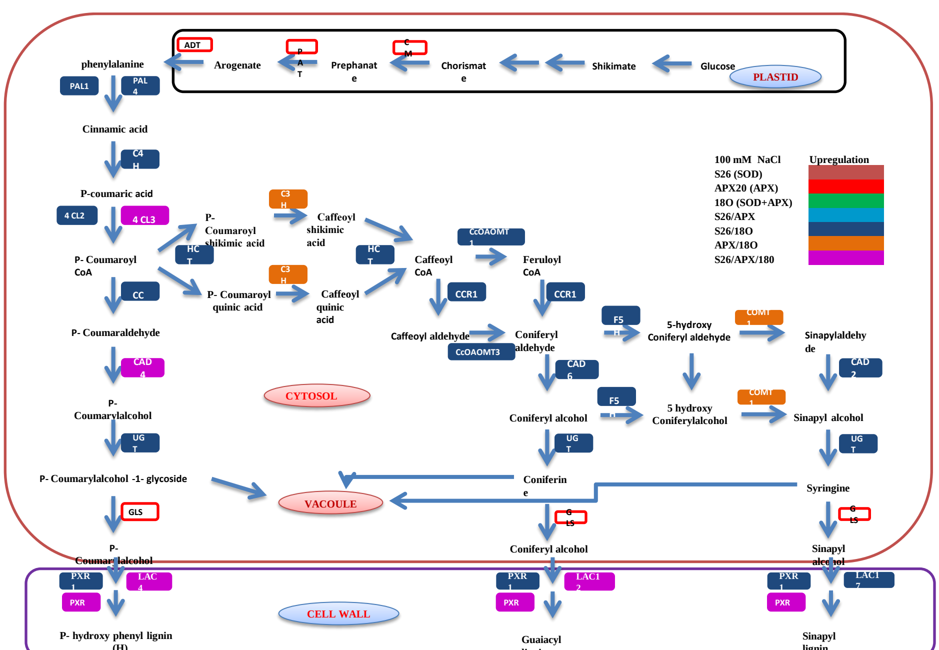
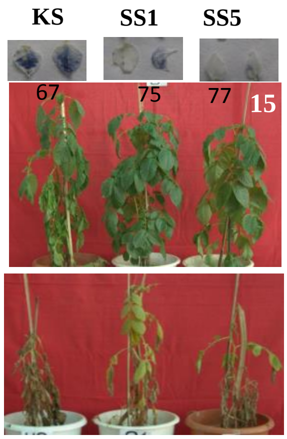


Figure 2. Diagram of the Monolignol biosynthesis upregulation in S26, APX20 and 18O under salt stress (100 mM) conditions in comparison to WT.
The "metabolic grid" shown in this scheme incorporates the results of the studies done through RNA-seq and qPCR. Each arrow shows a reaction in the pathway, and next to each arrow is the name of the enzyme that catalyzes the associated reaction , Abbreviations are listed as per pathway. CM, chorismate mutase; PAT, prephenate aminotransferase; AGT, arogenate dehydratase; PAL, phenylalanine ammonia lyase; C4H, cinnamate 4-hydroxylase ;4CL, coumarate:CoA ligase ; CCR, cinnamoyl-CoA reductase; CAD, cinnamyl alcohol dehydrogenase ; HCT, hydroxycinnamoyl-CoA transferase ;C3H, *p*-coumarate 3-hydroxylase; F5H, ferulate 5-hydroxylase ; COMT, caffeic acid *O*-methyltransferase ; UGT, UDP-glucosyltransferase; LAC, laccases; PXR, peroxidases; CCoAOMT, caffeoyl-CoA 3-O-methyltransferase; H lignin, p-hydroxy phenyl lignin; G lignin, guaiacyl lignin monomers; S lignin, syringyl lignin monomers.

			Day 0	Day 10	Day 20
Net photosynthetic rate [µmol(CO_2) m^{-2} s^{-1}] (40)	WT	control	11.71±0.42b	10.10±0.29bc	8.87±0.23cd
		stress	11.45±0.64b	8.85±0.53cd (−12.4)	5.10±0.05e (−41.8)
	SS5	control	15.42±0.83a	13.91±1.04a	10.47±0.63bc
		stress	15.16±0.24a	11.54±0.01b (−17.1)	8.01±0.70d (−23.5)



Recovery from Drought

Climate change

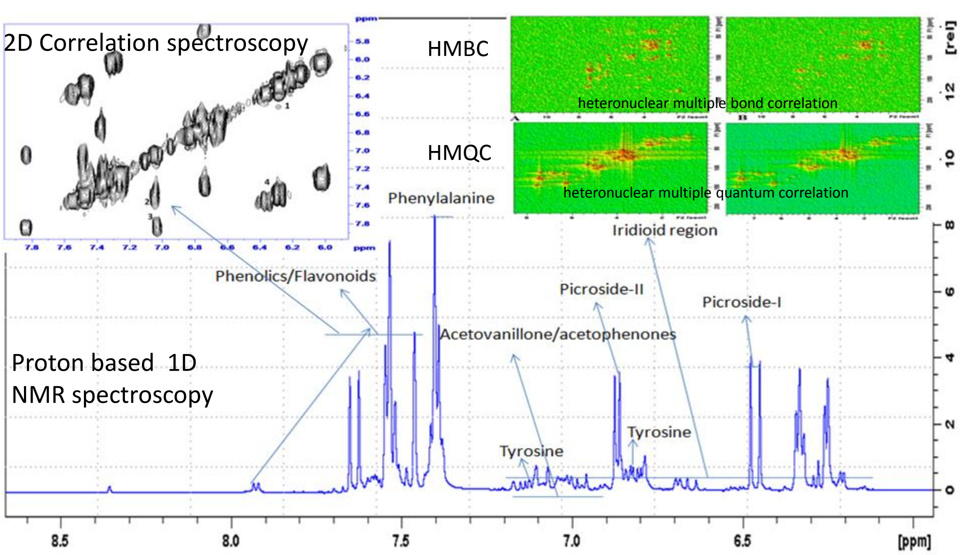
Drought/ HT Stress → $O2^{-\cdot}$ → Thermostable enzyme

Temperature rise

US Patents 7,037,697 and 6,485,950, US patent 20070269811; Biol Plant 57: 359-64 (2013)

Metabolic profiling of *P. kurroa*

NMR: Non destructive technique, no separation of analytes, sample can be recovered and used simultaneously for other purposes.



Plant response to Climate change:
Integration of crop modelling with genetic network

- Various models are available for assessment of the impact of global climate change, such as based upon soil-atmosphere exchanges of matter and energy; and physiological models.
- Inherently, these models do not incorporate the genetic control of plant processes that actually determines responses to environmental variables.
- Can we undertake to understand the genetic network response to the climate change? The information can be integrated in crop models for better and accurate prediction of the plant response to climate change. For such studies, crops such as wheat/rice can be used due to availability of models

The next major step toward sustainable growth is to improve the value of our products and services per unit of natural resources employed


2013
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Memorial Cricket Tournament
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Thank You .....!