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# **Climate Change and Agriculture: strategies for answering the challenges with Biotechnology**

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# Organization of the Talk



- I. Agricultural Biotechnology - Introduction**
- II. Mitigation of Climate Change**
- III. Adaptation to Climate Change**
- IV. Adaptation to Climate Change: Biotech and the future**
- V. Challenges to the adoption of Biotech crops**



# I. What is a GMO?



- 1. A conventionally bred variety?**
- 2. A variety bred using the tools of modern biotechnology?  
(Genetic Engineering)**



# I. Why Biotech?



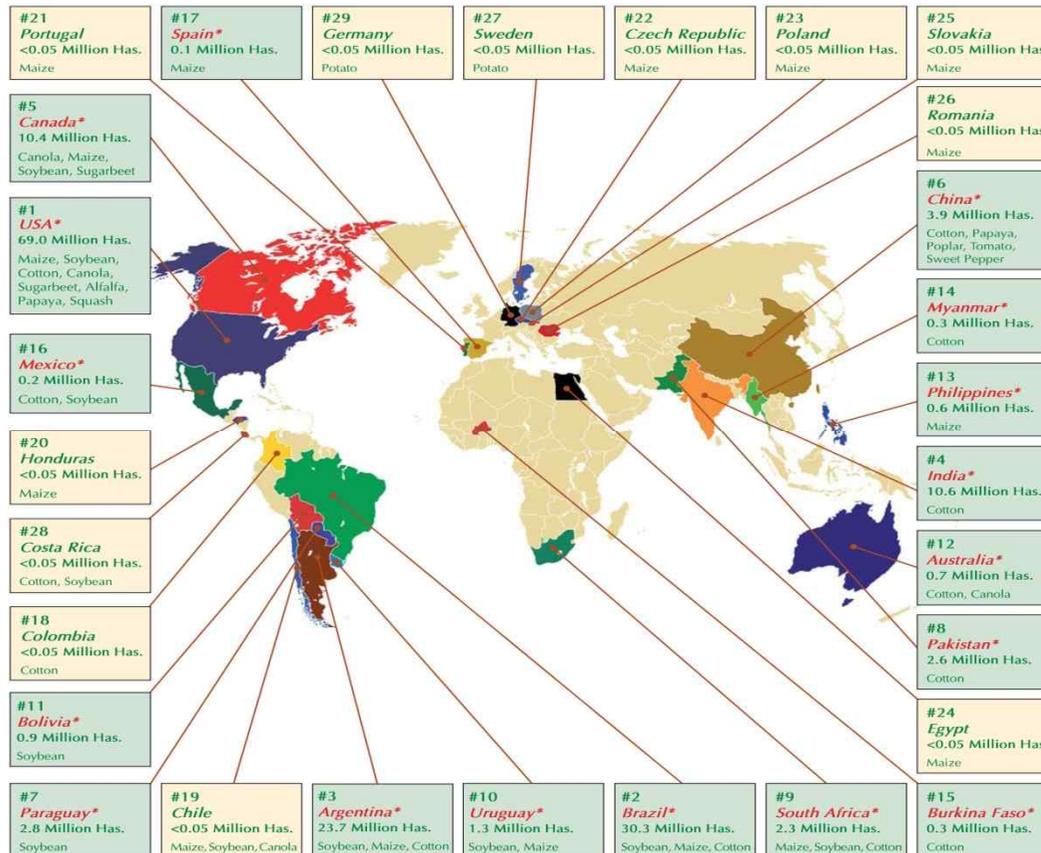
- Facilitate the moving genes from one species to another (sometimes)
  - Conventional hybridization may achieve the same goals but will take longer
  - Can also be used to move genes from one variety to another of the same species
- More accurate
  - Global gene expression levels differ less between transgenics and the conventional varieties from which they were derived, than between conventional varieties
- Faster development time
  - Time to commercialization can be reduced by <50%

Source: Cheng et al. J. Ag. Food Chem. 56 (2008)



# I. Worldwide Importance

Biotech Crop Countries and Mega-Countries\*, 2011



\* 17 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

Source: Clive James, ISAAA

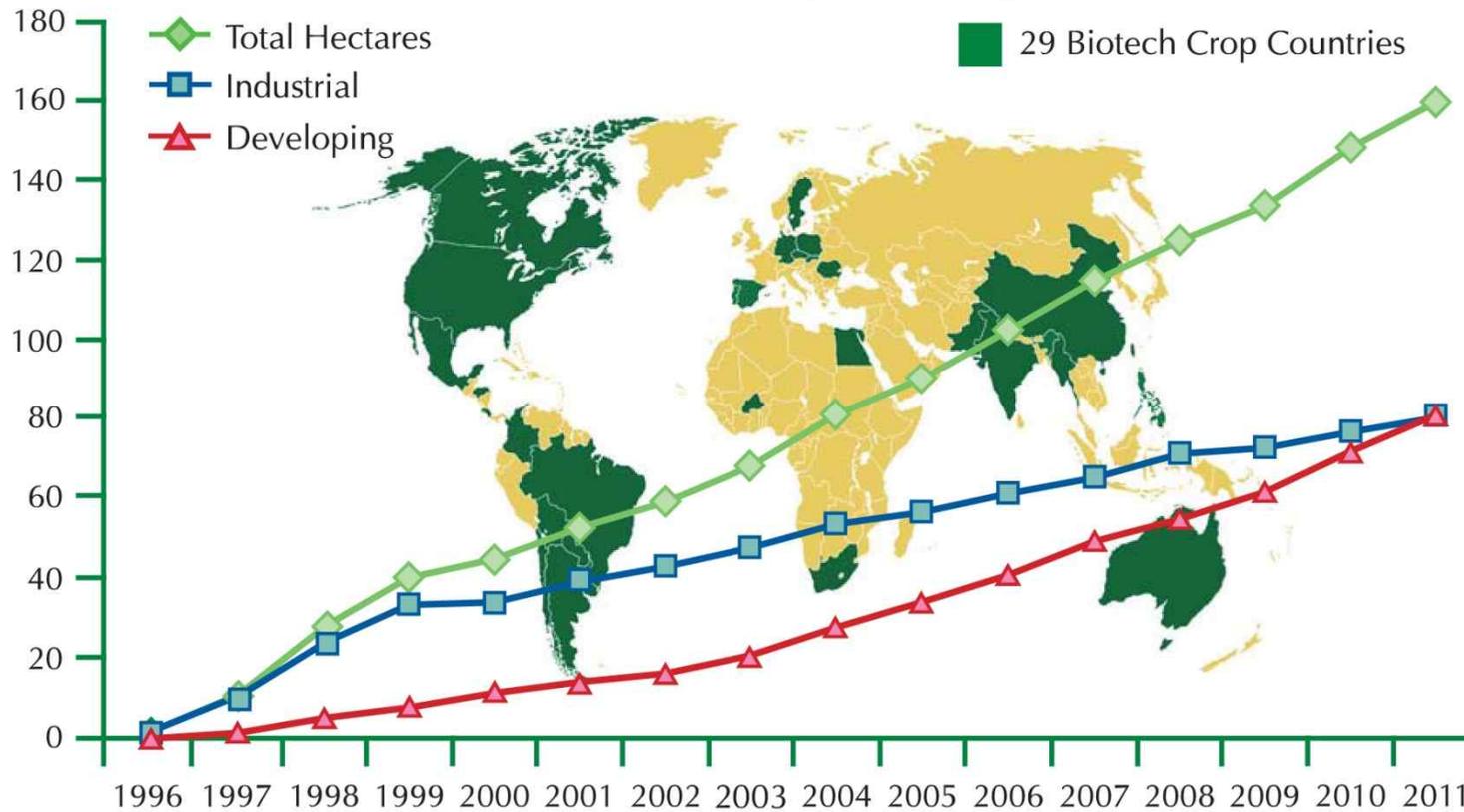
The number of countries growing Biotech crops increased to 29 in 2011



# I. Worldwide Importance



GLOBAL AREA OF BIOTECH CROPS  
Million Hectares (1996-2011)



Source: Clive James, ISAAA



# I. Biotech Traits



Until now almost all commercialized Biotech crops have two traits

- Herbicide tolerance  
(most Common is Glyphosate Resistance)

and/or

- Pest Resistance



# I. Biotech Crops: Adoption %



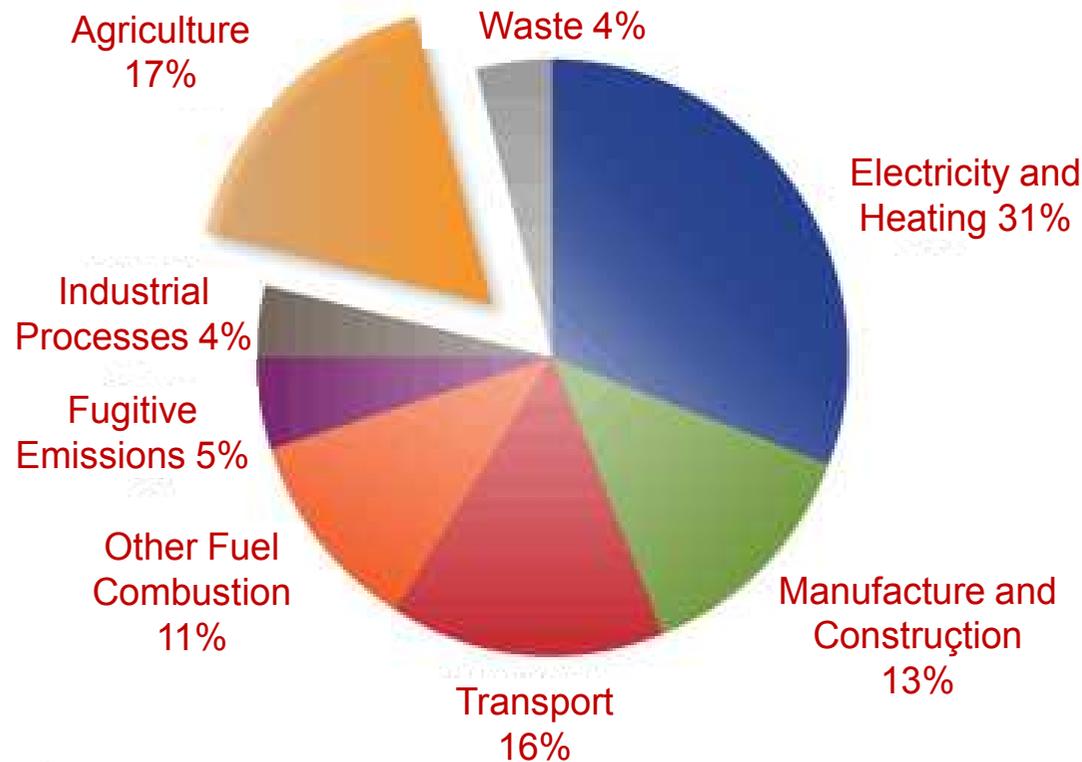
- **82% of Cotton grown in the world is Biotech (pest resistant)**
- **75% of Soybean grown in the world is Biotech (herbicide tolerant)**
- **32% of Maize grown in the world is Biotech (pest resistant and/or herbicide tolerant)**



## II. Mitigation of Climate Change



### Greenhouse gas Emissions by sector



Source: WRI 2008

**Agriculture is the second most important source of greenhouse gases**



## II. Mitigation of Climate Change



### **Conventional Agriculture is the second most important source of greenhouse gases**

- The synthesis and use of nitrogenous fertilizers is the principal cause
- The nitrogen is converted into Nitrous Oxide in the soil
- 1.2 metric tons of nitrogen → 10 metric tons GHG



## II. Mitigation of Climate Change: Present Generation of Biotech Crops



### Reduced Carbon Emissions due to Biotech Crops 2010



Source: Brookes and Barfoot 2012

- Reduced use of pesticides and Herbicides:  
 $1.7 \times 10^9$  kg.  $\text{CO}_2$
- Conservation Tillage:  
 $17.6 \times 10^9$  kg.  $\text{CO}_2$
- Total:  $19 \times 10^9$  kg.  $\text{CO}_2$   
 $\equiv$  Removing 9 million cars from the road
- Increased yields  $\rightarrow$   
 $\downarrow$  deforestation  $\rightarrow \downarrow \text{CO}_2$



## II. Mitigation of Climate Change: Next Generation of Biotech Crops



### Nitrogen Use Efficiency (NUE)



NUE Canola

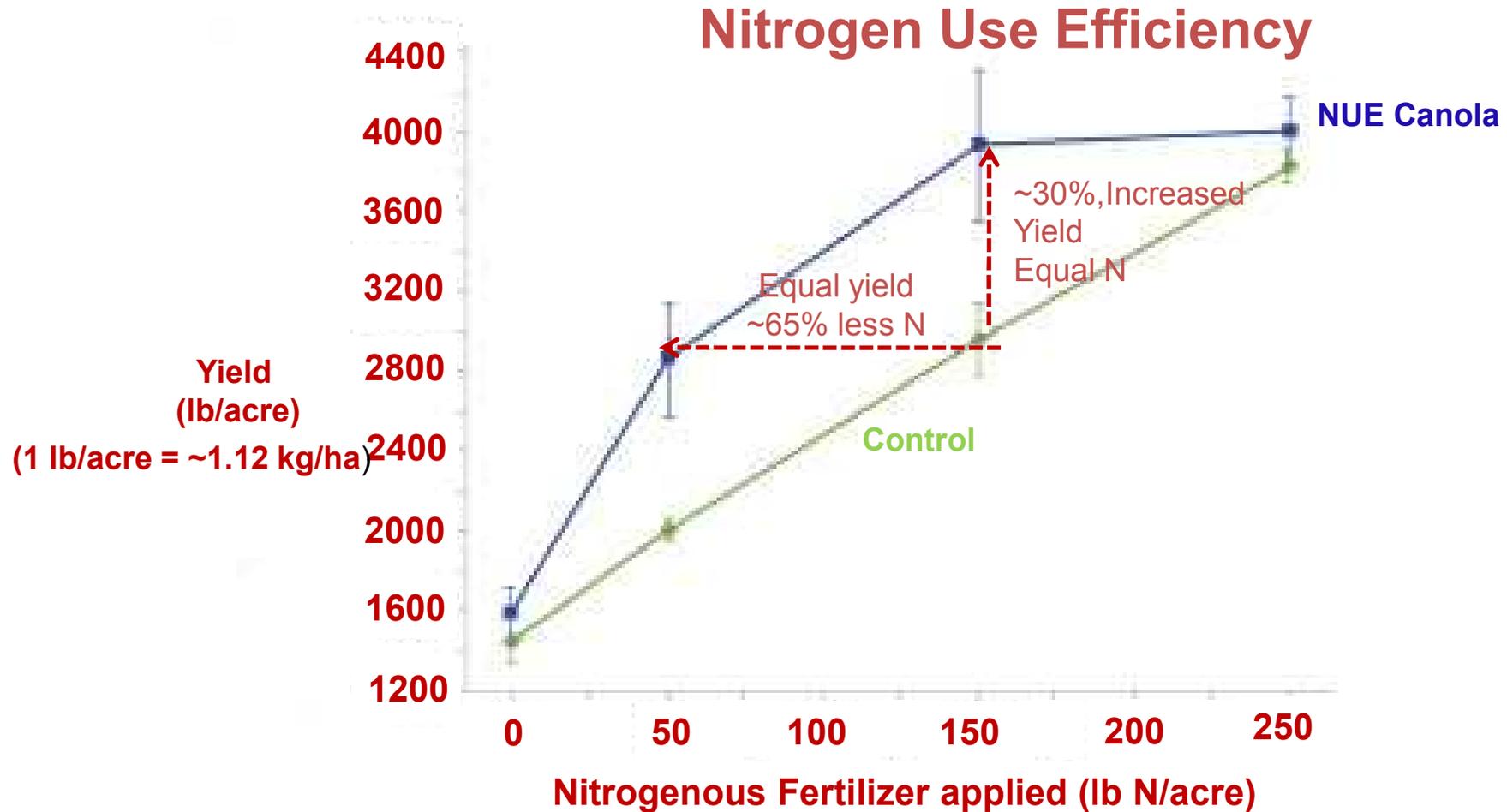
Conventional Canola

Source: Arcadia Biosciences Inc.

The transfer of alanine amino transferase gene, derived from Barley. Similar genes can be found in other plant species



## II. Mitigation of Climate Change: Next Generation of Biotech Crops



Source: Arcadia Biosciences Inc.

St. Petersburg October 8 2102



## II. Mitigation of Climate Change: Next Generation of Biotech Crops



**NUE Rice**

**Control**

**Nitrogen  
Use  
Efficiency**

Source: Arcadia Biosciences Inc.



## II. Mitigation of Climate Change: Next Generation of Biotech Crops



### Transgenic (GM) NUE Varieties under Development

- Wheat
- Barley
- Maize
- Rice
- Canola
- Rape



## II. Mitigation of Climate Change: Next Generation of Biotech Crops



### Who is working to develop transgenic NUE varieties? (partial list)

- National and Multinational Companies
  - Monsanto
  - BASF
  - Arcadia Biosciences (USA)
- Universities
  - University of Alberta (Canada)
- Government Research Institutes
  - ICABIOGRAD
  - CSIRO (Australia)



## **III. Adaptation to Climate Change: Next Generation of Biotech Crops**



- 1. Varieties with increased drought tolerance**
- 2. Varieties with increased tolerance to flooding**
- 3. Varieties with increased tolerance to salinity**



## III. Adaptation to Climate Change: 1. Losses due to Drought



- Average annual losses in yield in tropical regions are ~17%
- In 1991-1991, yield losses in Southern Africa reached ~60%



# III. Adaptation to Climate Change: 1. Drought Tolerance

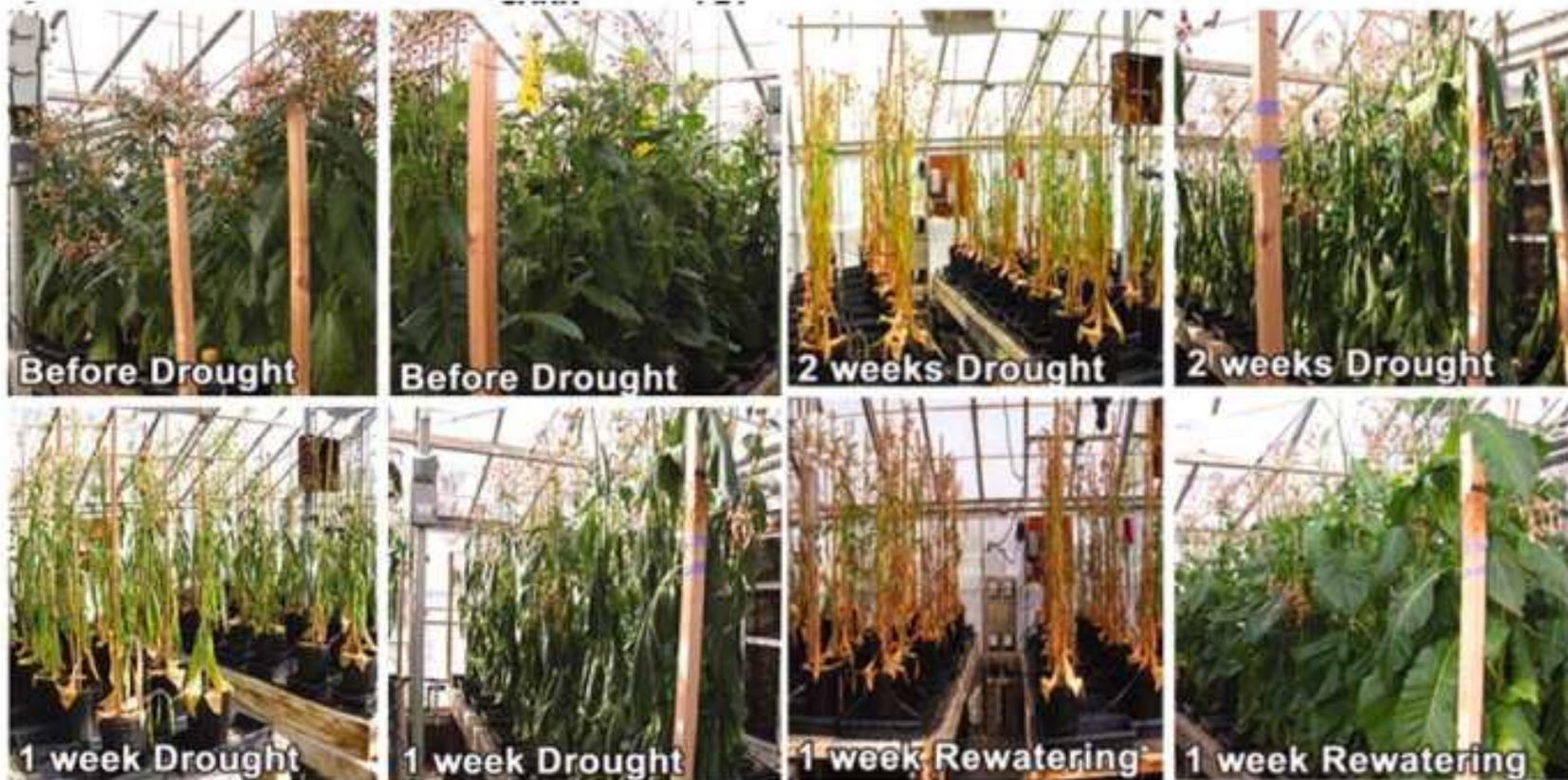


**Control**

**Transgenic**

**Control**

**Transgenic**



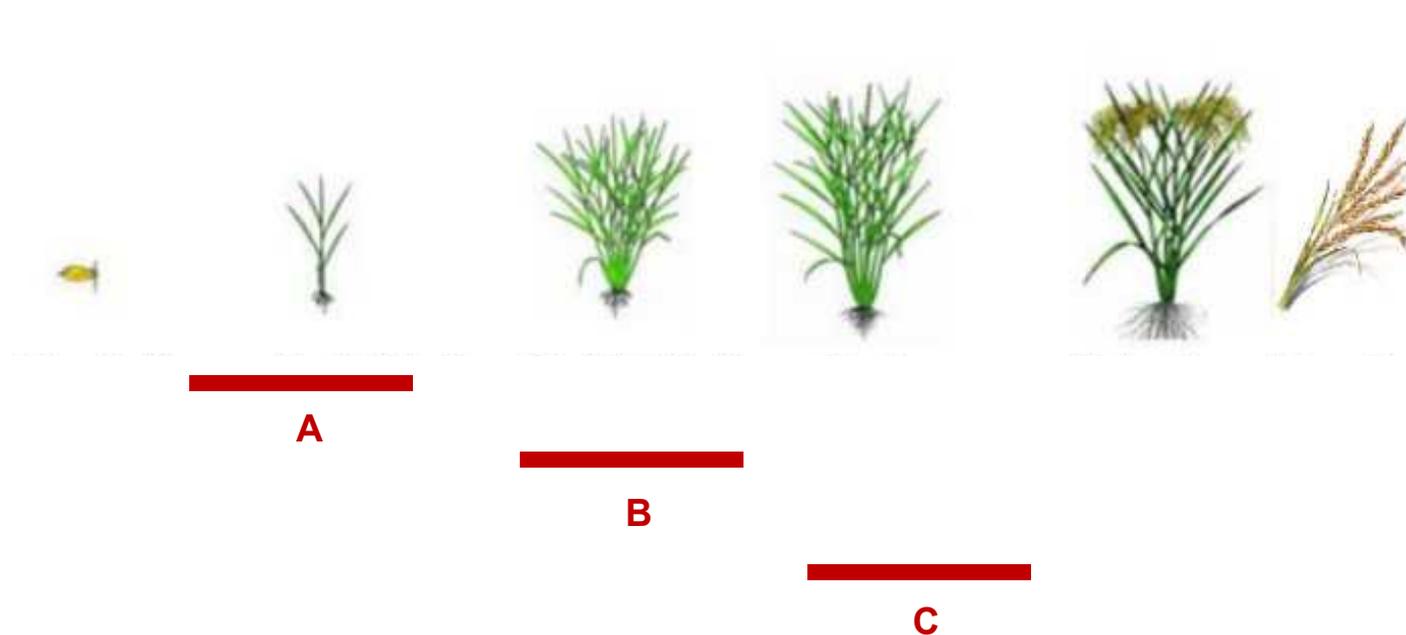
Source: Arcadia Biosciences Inc.



# III. Adaptation to Climate Change: 1. Drought Tolerance



## Drought during different stages in the Rice growth cycle



Source: Arcadia Biosciences Inc.



# III. Adaptation to Climate Change: 1. Drought Tolerance



## Control



**A B C -**

## Transgenic Rice



**A B C -**

Source: Arcadia Biosciences Inc.



## III. Adaptation to Climate Change: 1. Drought Tolerance



### In Process of Commercialization

- Indonesia (sugar cane) 2012 →
- USA: 2012 →
  - Private Sector(Monsanto , Syngenta, Pioneer)
- South Korea (Rice)
- Sub-saharan Africa: 2015 →
  - Public-Private Partnership  
Coordinated by the African Agriculture Technology  
Foundation (AATF):  
Participation by Monsanto, The Gates Foundation, CIMMYT,  
and National African Programs



# III. Adaptation to Climate Change: 2. Flood Tolerance



Tolerant  
Line



Susceptible  
Lines

Source: JACKSON, M. B. et al. 2003 Ann. Bot. 91:227-241

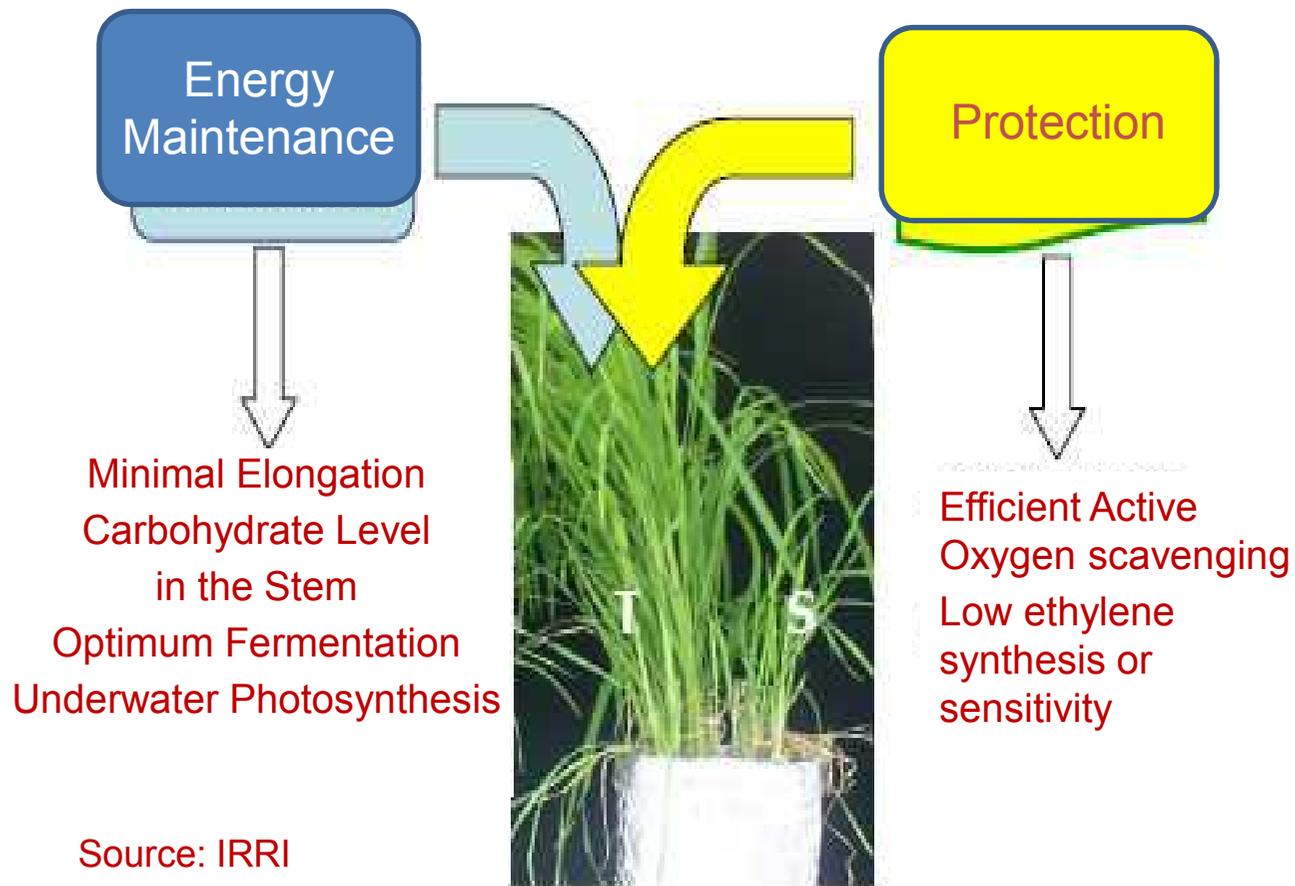
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# III. Adaptation to Climate Change: 2. Flood Tolerance



## Traits which are associated with flood tolerance





## III. Adaptation to Climate Change: 2. Flood Tolerance



Who is working to develop such varieties? (partial list)

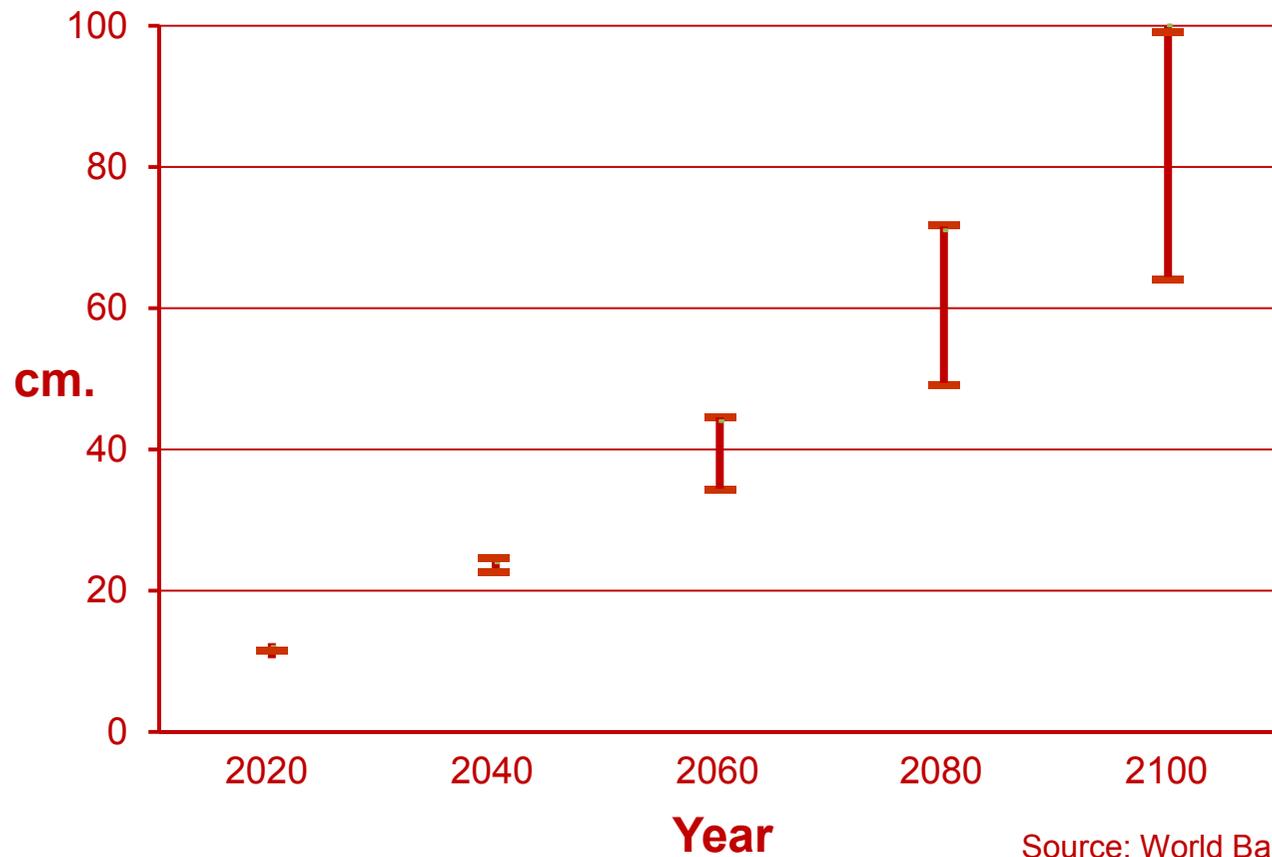
- Universities in California (USA)
- IRRI: Los Baños, The Philippines



# III. Adaptation to Climate Change: Rise in Sea Levels



## Projected Sea Level Rise in Vietnam



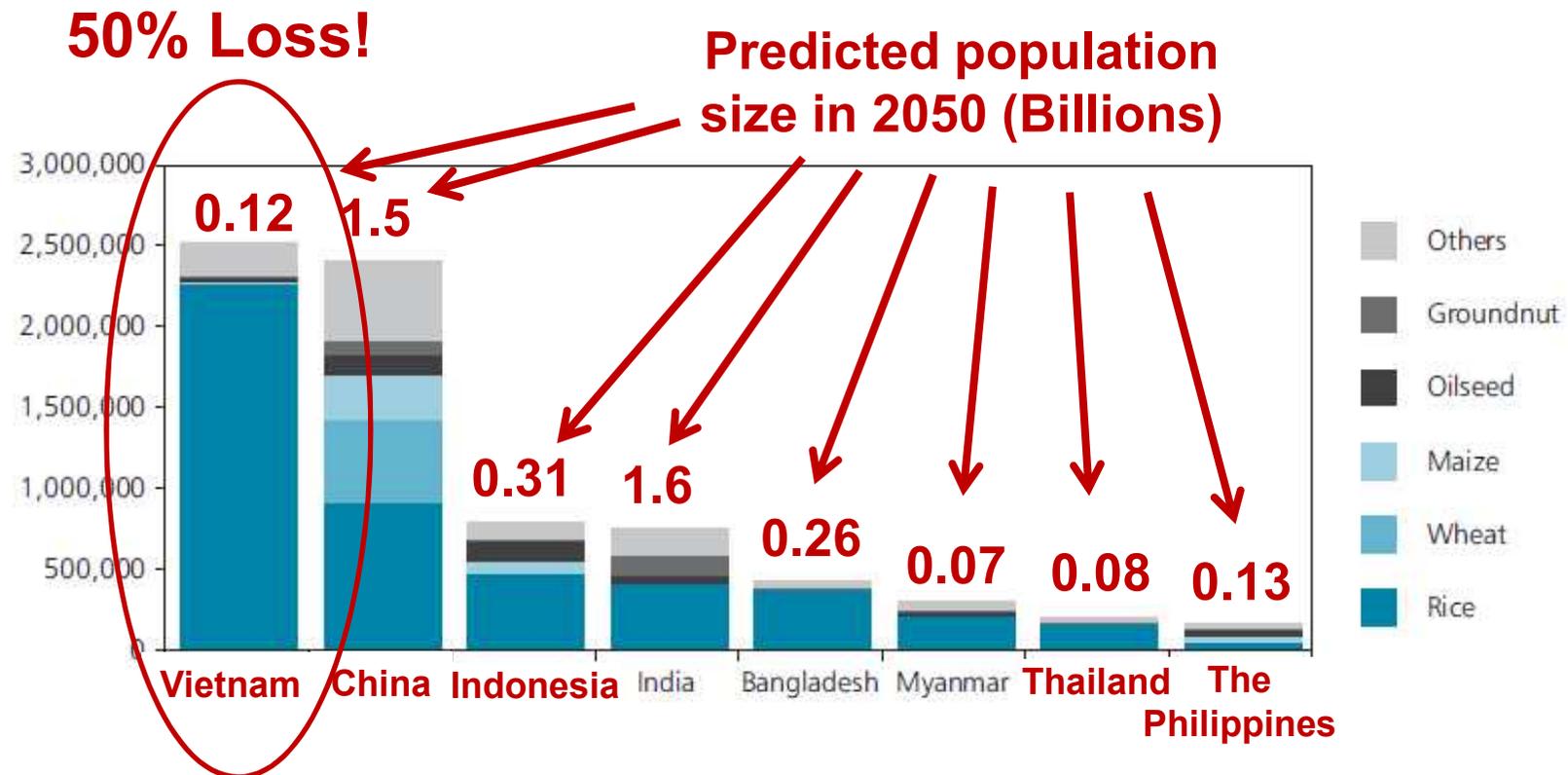
Source: World Bank



# III. Adaptation to Climate Change: Rise in Sea Level



## Hectares lost due to rise of 1 meter in sea level



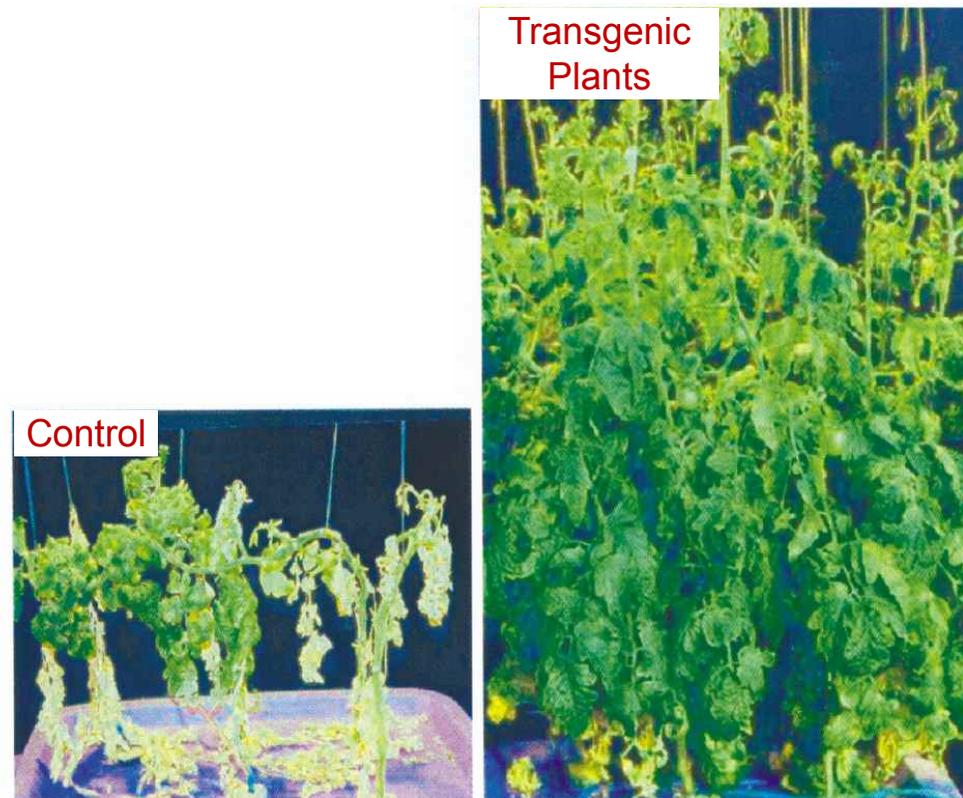
Source: Asian Development Bank; UNPFA



# III. Adaptation to Climate Change: 3. Salt Tolerance



## Tolerance to 200 mM NaCl In Tomato Plants



Source: E. Blumwald U.C. Davis



## III. Adaptation to Climate Change: 3. Salt Tolerance



### Two mechanisms for salt tolerance

1. Restriction of Salt uptake by the plant
2. Sequestration (and concentration) of salt in sub-cellular compartment
  - Possible use in bioremediation of soils with high levels of salt
  - Lack of necessity to add salt to forage for animals



## III. Adaptation to Climate Change: 3. Salt Tolerance



### Transgenic (GM) NUE Varieties under Development

- Corn
- Cotton
- Rice
- Sorghum
- Tomato
- Wheat
- Rice
- Sugarcane



## III. Adaptation to Climate Change: 3. Salt Tolerance



### Who is working to develop transgenic salt tolerant varieties? (partial list)

- National and Multinational Companies
  - Arcadia Biosciences (USA)
  - MAHYCO (India)
  - Du Pont Pioneer
- Universities
  - University of California at Davis
  - University of Toronto Alberta
- Government and International Research Institutes
  - Japan National Institute of Agrobiological Sciences
  - IRRI



## IV. Adaptation to Climate Change: The Future



- Development of Biotech varieties tolerant to heat
  - An increase of 1 °C in night-time minimum temperatures is associated with a loss in yield of 10%  
Source: Peng *et al.* 2004 PNAS 101:9971-9975.
- Development of Biotech varieties which take advantage (increased photosynthesis levels) of high CO<sub>2</sub> levels



## V. Challenges to the adoption of Biotech crops: Acceptance



### Beyond Science and Economics

- Trade competition and retaliation
- Technological gaps and science literacy
- Concerns about Food System Control (Multinationals)
- Consumer “right to know”
- Public does not relate to present generation of Biotech crops (Pest Resistant and Herbicide Tolerance)



## V. Challenges to the adoption of Biotech crops: Regulation



Overly stringent regulations as well as the lack of policies and regulatory mechanisms

- discourage investments in research into the next generation of crops
- causes costs to fall disproportionately on smaller importers (often developing countries)
- are effective technical barriers to trade
- Increase the cost of food and feed



**Thank you for your attention Les agradezco su atención**

**谢谢您的关注**

**Terima kasih**

**ご清聴 ありがとうございます**

**Спасибо за внимание**

**제 발표를 경청해주셔서 감사합니다**

**Terima kasih atas perhatian  
anda**

**Maraming salamat sa  
inyong pakiking**

**ขอบคุณ**

**Cảm ơn quý vị đã lắng nghe**