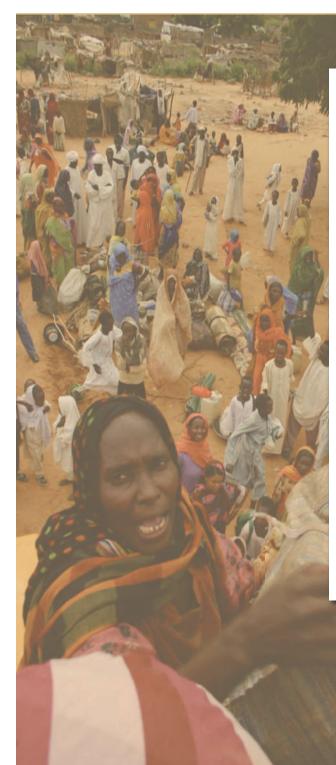
## Genetically Engineered Crops: Can Developing Countries Really Benefit?



Peggy G. Lemaux Dept of Plant and Microbial Biology lemauxpg@berkeley.edu; http://ucbiotech.org







## Hunger grips 1 billion people

U.N. says numbers climbing even though food prices fell

#### By JENNY BARCHFIELD Associated Press

PARIS — The number of hungry people in the world could soon hit a record 1 billion, despite a recent drop in food prices, the U.N. food aid organization said Wednesday, May 6.

The recent financial crisis, though it has helped bring global food prices down, also has led to falling trade and lower development aid, said the Food and Agriculture Organization's general director, Jacques Diouf.

As a result of the crisis, an additional 104 million people were likely to go hungry this year — meaning they receive fewer than 1,800 calories a day, Diouf told reporters after a two-day meeting in Paris between the FAO and the Organization for Economic Cooperation and Development.

"We have never seen so many hungry people in the world," Diouf said.

The number of people considered hungry increased last year as well, by 40 million, and in 2007, when 75 million more people joined the ranks, Diouf said.

If the projection for 2009 proves accurate, that would

mean that about 1 billion people — or roughly one-sixth of the world's population — will hungry by the end of the year, he said.

"Food security is a matter of peace and security in the world," he said, stressing that the food production will have to double by 2050 just to keep pace with population growth.

Despite a 30 percent drop in food prices from June 2008, overall food prices still remain above 2006 levels, Diouf said. In the developing world, however, food prices have dropped only 12-14 percent since June 2008, he said.

Surveys show that prices of basic staple foods in many poor countries have barely registered any drop.

Higher food prices spurred a 12-13 percent increase in production in wealthy countries. But developing countries — excluding giants such as China, Brazil and India have only seen a 0.4 percent rise in food production, "which is totally offset by the increase in population," Diouf said.

Systemic problems — such as weak infrastructure and dependence on rain — are to blame for poor nations' nearstagnant production. Bad roads in rural areas, lack of proper food storage facilities and a lack of irrigation infrastructure continue to keep farmers in poor countries from producing more, Diouf said.



SOURCE: "Hunger grips 1 billion people", Capital Press, May 8, 2009. http://www.capitalpress.info/main.asp?Search=1&ArticleID=51096&SectionID=67&SubSectionID=782&S=1 One billion people in the world are starving – that's one in every six people on this planet and...





...and 30 to 50% of the world's population suffers from micronutrient malnutrition involving Vitamin A, iron and iodine.

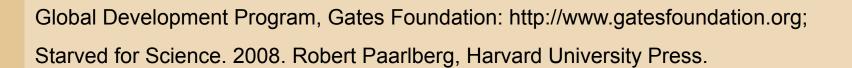


### Perspective on agriculture in developing countries...

#### How much will you spend on your lunch today?

- One billion of the world's poorest people live on ≤ \$1 per day and depend on their own agriculture for food.
- ✤ 820 million people go to bed hungry each day
- Malnutrition leads to stunted physical/mental development, increased disease susceptibility
- No country has rapidly moved out of poverty without increasing agricultural productivity
- Two-thirds of Africans are small farmers; most are women often with fewest resources







#### "Now Serving 9 Billion:

#### A Global Dialogue on Food Needs for the Next Generation"

(http://vimeo.com/9450194) on Feb. 12, 2010 with:

Nina Federoff, Gale Buchanan, Mark Cantley, Robert Paarlberg, Calestous Juma

What are major challenges of feeding 9 billion people by 2050?

- **1. Population Increase**
- 2. Amount of arable land
- 3. Fresh water availability

- 4. Movement to meat-based diet
- 5. Obesity
- 6. Politics of managing knowledge

What do we need to do to meet these challenges?

- 1. Simplify regulations
- 2. Invest in developing new crops
- 4. Larger investment in agricultural
  - research
- 3. Invest in adaptation of old crops 5. Reform educational system to better train ag professionals



#### **United States**



Senegal

## Technologies available for agriculture in many parts of Africa are different from that in the developed world...



# Also crop productivity is different in developed vs. developing countries where yields are lower.

	tare)				
CROP	Kenya	Ethiopia	India	Developed	
				World	
Maize	1,640	2,006	1,907	8,340	5X
Sorghum	1,230	1,455	797	3,910	5X
Rice	3,930	1,872	3,284	6,810	~3X
Wheat	2,310	1,469	2,601	3.110	2X
Chickpea	314	1,026	814	7,980	25X

#### WHY?

For many reasons...among them is that varieties giving higher yields are not optimized genetically for their environments.



### **United Nations Development Programme**

Human Development Reports

### Two views of the role of technology...

Human Development Reports

Home > HD Reports > HDR 2001

Events & News

"Technology networks are transforming the traditional map of development, expanding people's horizons and creating the potential to realize in a decade progress that required generations in the past", but...

"Complex problems of hunger and agricultural development will not be solved by technological silver bullets." Peter Rosset, Food First

Chapters

Foreword, Acknowledgements, Abbreviations, Contents, Overview

Chapter 5: Global initiatives to create technologies for human development (457KB)

Chapter 4. Onleasting human creativity hadonal strateg

Human Development Indicators (898KB)

Addendum: Human Development Index for 12 countries not included in main indicator tables (11KB)

Errata

Complete publication in one big file (3.3MB)

#### all PDF files

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Letter from Mr. Djibril Diallo, Director, Communications Office, Office of the Administrator, UNDP

Interactive

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U N D P

Human Development Index

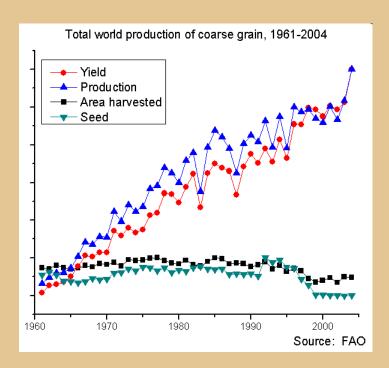
New technologies key to reducing world poverty

Although controversial,



Norman Borlaug, father of the Green Revolution, upon receiving the Congressional Gold Medal in 2006 for developing higher yielding rice and wheat varieties, said...





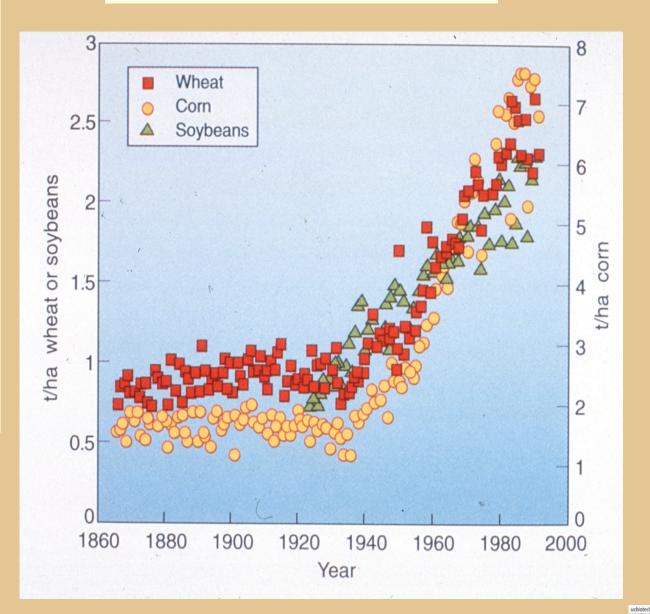
"The battle to ensure food security for hundreds of millions of miserably poor people is far from won. World peace will not be built on empty stomachs..."

"It is within America's <u>technical</u> and financial power to help end this human tragedy and injustice, if we set our hearts and minds to the task."

Starting in the 1930's this was achieved using classical breeding. Two plants – each with desirable traits were crossed and progeny physically screened to identify plants with the desirable traits from both parents

This resulted in impressive yield increases in the major crops

#### Yel here by year





 1930
 2009

 % of people involved in farming:
 21%
 ~0.7%

 Number of farms:
 6,295,000
 2,200,000

 Average acreage per farm:
 157
 418

But productivity of average U.S. farmer... In 1930 fed 10 In 1960, 24 In 1990, 100 In 2009, 155









http://www.agcensus.usda.gov/Publications/2007/Full\_Report/Volume\_1,\_Chapter\_1\_US/st99\_1\_063\_063.pdf http://prb.org/Datafinder/Geography/Data.aspx?category=6&region=72&region\_type=3



An approach that speeds classical breeding approaches utilizes genomic information to develop markers. Marker-assisted breeding led to a new millet brid with powdery mildew resistance



Another genetic approach that is beginning to be utilized in Africa is the use of genetically engineered crops –



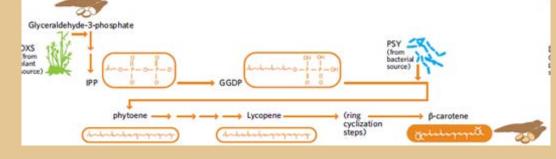
What's in the pipeline for developing countries?



#### **Goal for BioCassava Plus**

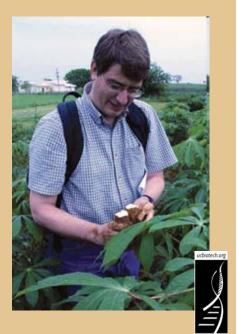
Nutritional modifications to increase iron, zinc, protein, vitamins, and virus resistance in cassava.





Insertion of both the *psy* and *dxs* genes resulted in an orange cassava with 30X beta-carotene than normal roots.

"It's this regulatory tangle facing GM crops in much of the world, including Africa, that largely explains why many transgenic plants that could address widespread nutrient deficiencies are trapped in laboratories instead of growing in soil."



Uganda plans to start testing for wilt resistance in genetically modified bananas, using a gene from sweet pepper



## Engineered maize variety resistant to maize streak virus - endemic to sub-Saharan Africa





SOURCE: Shepherd, D.N., Mangwende, T., Martin, D.P., Bezuidenhout, M., Kloppers, F.J., Carolissen, C.H., Monjane, A.L., Rybicki, E.P. and Thomson, J.A. 2007. Maize streak virus-resistant transgenic maize: a first for Africa. Plant Biotechnology Journal, online first (doi: 10.1111/j.1467-7652.2007.00279.x).



Bt cotton gives 15% yield increase under low to moderate pest infestation; insecticide use reduced 2/3 in Burkina Faso

SOURCE: Vitale, J., Glick, H., Greenplate, J., Abdennadher, M. and Traoré, O. 2008. Second-Generation Bt Cotton Field Trials in Burkina Faso: Analyzing the Potential Benefits to West African Farmers. Crop Science 48:

## GE sweet banana field tested in Uganda for Black Sigatoka fungus resistance



Tuber moth-resistant GE potato to reduce \$5M yearly losses to smallscale African farmers



SOURCE: http://greenbio.checkbiotech.org/news/2008-09-02/GM potato\_blessing\_for\_small\_farmers\_South\_African\_group/



## Water Efficient Maize for Africa (WEMA) will use marker-assisted breeding and biotechnology to develop African maize varieties



## Beetle-resistant Eggplant developed in India, but...

Jeffrey Smith, author of Seeds of Deception, urges Indian state of Orissa to reject Bt brinjal, Bt cotton

SOURCE: "1st GM eggplant soon to be commercially grown in RP", The Philippine Star,

## What are some of the questions being asked about these GE crops?

- **\***Are GE crops being grown in developing countries?
  - Will they address small acreage farmers' needs?
    - **\***Why are they growing them?
- **\***Are there regulatory and consumer acceptance issues??
  - Is this a magic bullet for food security







in Africa?

## Are GE crops grown in developing countries?

#### Industrial and Developing Countries (M Has, M Acres) **M** Acres 346 140 296 120 ---- Total 247 100 -D- Industrial ----- Developing 198 80 148 60 99 40 49 20 0 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 Source: Clive James, 2009

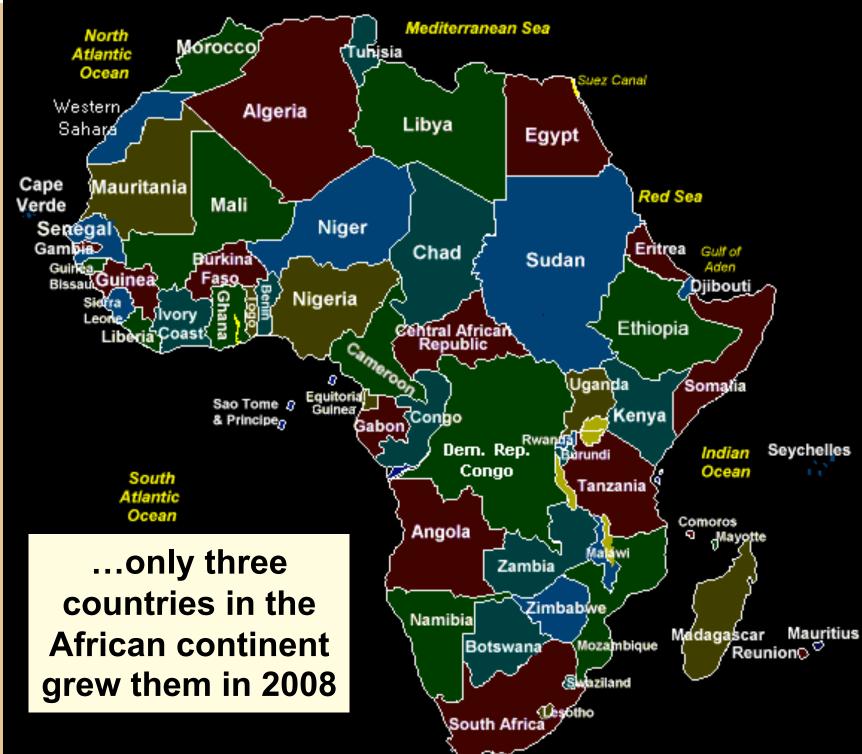
Global Area of Biotech Crops, 1996 to 2008:

482,812 square miles worldwide in 2008 (equal to combined areas of CA, TX and NY) in 25 industrial and developing countries

> But the variety of GE crops is limited and...

**25** industrial and developing countries in order of acreage:

United States, Brazil, Argentina, India, Canada, China, Paraguay, South Africa, Uruguay, Bolivia, Philippines, Australia, Burkina Faso, Spain, Mexico, Chile, Colombia, Honduras, Czech Republic, Portugal, Romania, Poland, Costa Rica, Egypt, Slovakia.



uchiotech or



Will GE crops address small farmers' needs?

"Economic evidence does not support misconception that transgenic crops only benefit large farms; evidence indicates technology might actually be 'pro-poor."

(Ruttan VW 2004. Intl J Biotechnol 643-54)



What does "pro-poor" mean?

## How can this technology be pro-poor?

**Evidence for Bt Cotton Gains** 

Bt cotton in:

- United States yield increase 0 15%
- China yield increase 10%
- South Africa yield increase 20%-40%
- India yield increase 60 80 %

Ref: : Qaim M and Zilberman D. 2003. Science 299:900-902

Another study, using data collected by researchers on field trials of 9000 farming families in India, found a 45-63% higher yield with Bt vs. nonBt cotton.

Ref: Bennett et al., 2006. Rev Agric Econ 28: 59-71

Reason for difference: Small-scale farmers suffer bigger pestrelated yield losses due to technical and economic constraints





Yield indications for first research season for different survey areas.	Site	Variety	Mean yield (kg/kg)	п	Yield difference (kg/kg)	<i>t</i> -value	% yield difference			
	Avg. all fa	Avg. all farmers								
	U	Own seed	63							
		<b>CRN</b> seed	187	175	59	8.679	32%*			
		Bt seed	246							
	Individua	l Sites:								
	Northern	Northern Highveld								
		Own seed	32							
		CRN seed	90	33	56	4.490	62%*			
		Bt seed	146							
	Southern	Southern Highveld								
		Own seed	162							
		CRN seed	278	57	57	4.332	21%*			
		Bt seed	335							
	Hlabisa	Own seed	78							
Following introduction, figures show										
small-scale farmers are getting										

## Following introduction, figures show small-scale farmers are getting increased yields and better quality with Bt maize.

 CRIV SEEU
 9.5
 2.2
 3.2
 2.004
 5470\*

 Bt seed
 127
 \*Yield difference statistically significant at a 95% level.

 Gouse et al., 2006. Three Seasons of Subsistence Insect-Resistant Maize in South Africa: Have Smallholders Benefited? AgBioForum 9(1)-2



## Zimbabwe and Zambia stand united on GMOs



THE HERALD (Harare) Wisdom Mdzungairi October 11, 2005

International scientists, including those from the United States, have praised Zimbabwe and Zambia for rejecting genetically-modified food donations from the West to feed scores of their rural folk facing drought-induced food shortages.

Some African countries have taken strong stands <u>against</u>, some <u>for</u> GE crops, leaving policymakers and the public confused. Development of regulatory frameworks for many nations has been difficult.

reliable information and guidance available to the groups."



## In-depth look at two genetically engineered crops for developing countries



Public sector: Development of Golden Rice

Public-Private sector partnership: Development of SuperSorghum

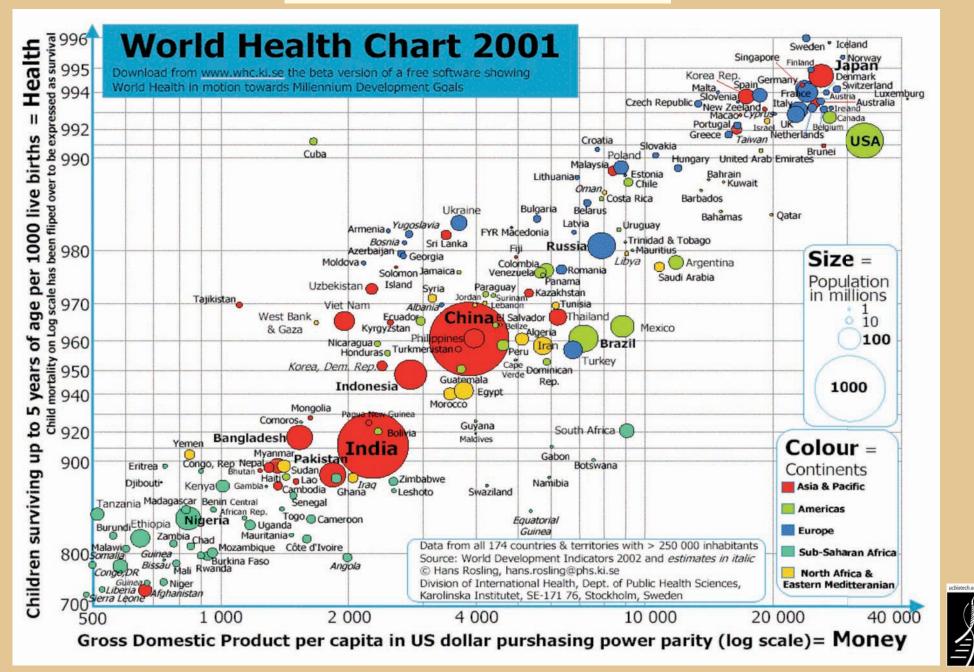




Public sector: Development of Golden Rice



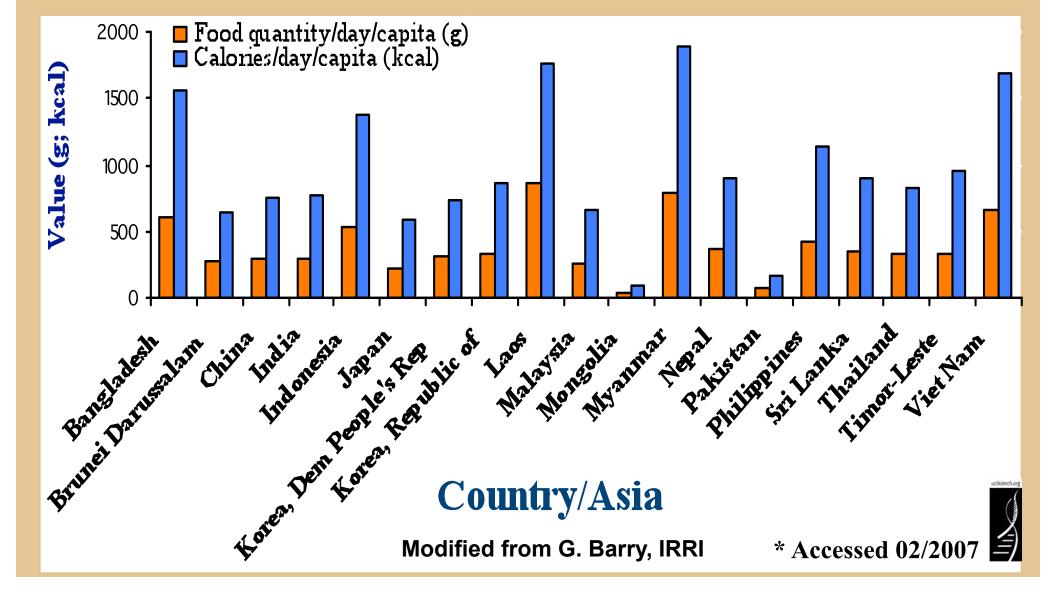
### Wealth vs. Health



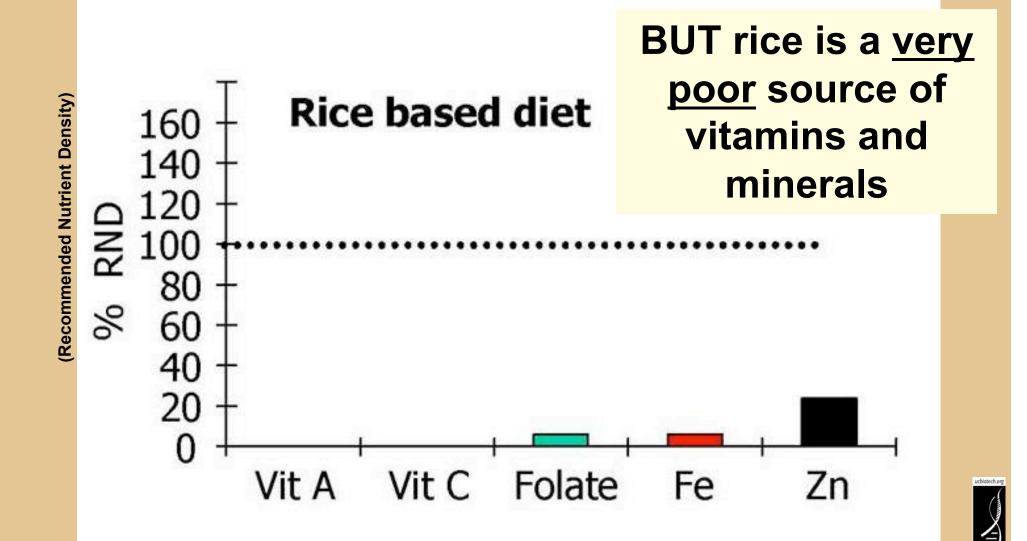
From: http://www.gapminder.org/

# Rice: Critical part of diets for many in less developed countries

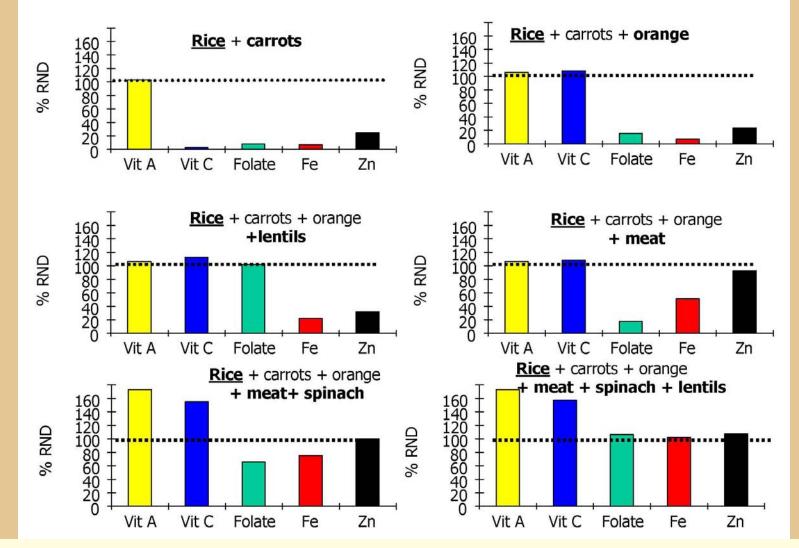
FAO Minimum Dietary Energy Requirement = 1800 – 2000 (weighted average; kcal/person/day)



## **Rice Diet and Micronutrient Nutrition**



From: "Nutrition: A Cornerstone for Human Health and Productivity", Richard J. Deckelbaum. Modified from G. Barry, IRRI Seminar, Earth Institute of Columbia University, April 14, 2005



Rice diet can be supplemented with other fruits, vegetables and meat to acquire needed nutrients...but not everyone has that luxury



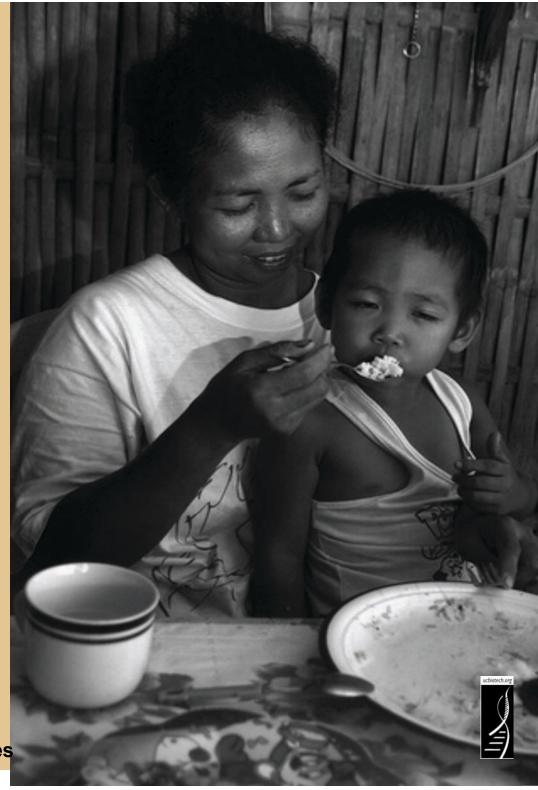
: "Nutrition: A Cornerstone for Human Health and Productivity", Richard J. Deckelbaum. Seminar at The Earth Institute of Columbia University, April 14, 2005

# The facts in the Philippines are...

- 2 of 3 infants (6mos.-1yr) have iron-deficiency anemia
- 1 of 3 Filipinos are at risk of <u>low</u> <u>zinc</u> intake
- 4 of 10 children are <u>vitamin A</u> <u>deficient</u>
- Numbers are increasing since 1990s

Micronutrient malnutrition is a serious public health problem

Emilia Boncodin, Fedl Budget Secy Manila Philippines



# Biofortification can complement other current interventions.



Food Fortification

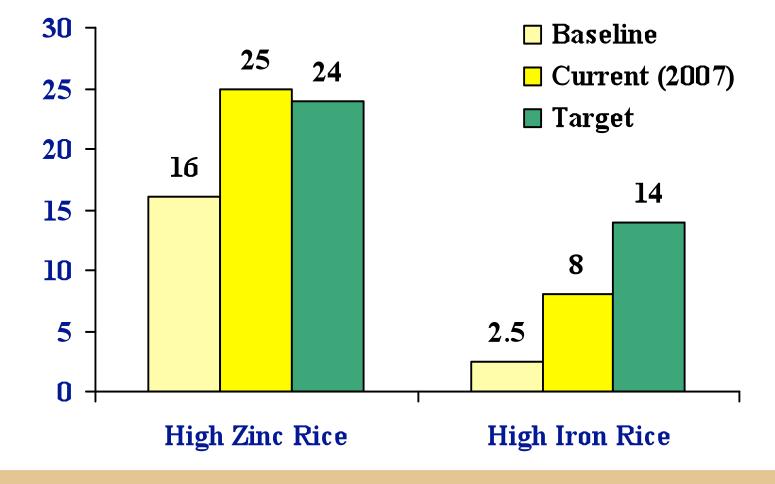
### Dietary Diversity

### **Biofortification**



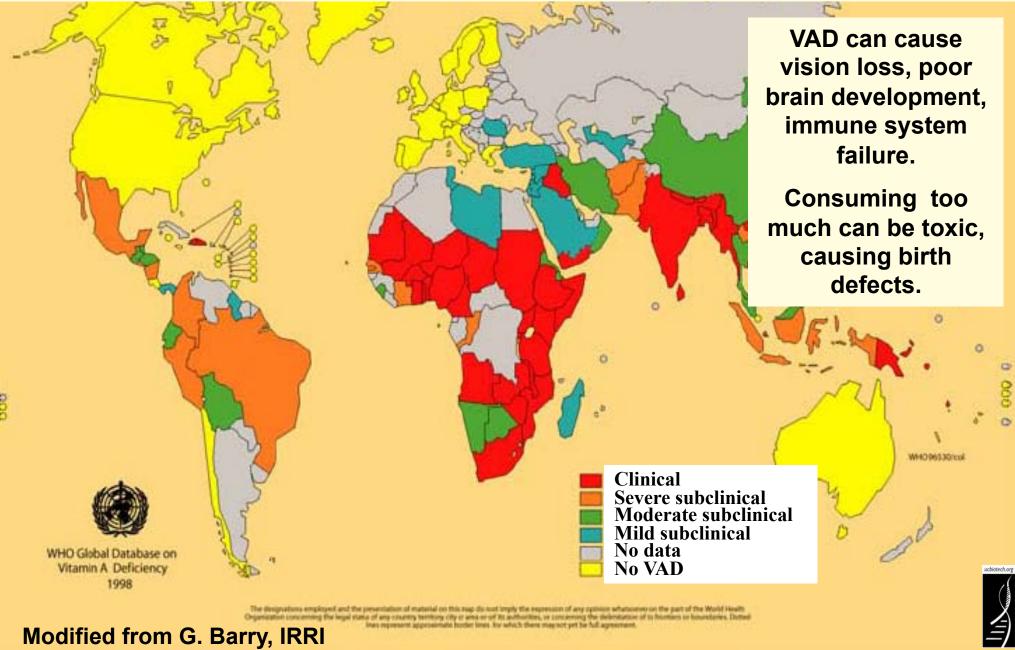
Modified from G. Barry, IRRI

# IRRI has made progress on iron and zinc biofortified rice...



E. Boncodin, Fedl Budget Secy Manila Philippines

### Vitamin A deficiency (VAD): as judged by severity of health impact



# Types of Golden Rice

GR1 and GR2 developed by Syngenta, donated to GR Humanitarian Board for use in developing countries by GR Network



# NO MAGIC BULLET

GR2 has 23-fold increase; normal portion provides half of a child's Vitamin A needs

1.2 – 1.8 up to 8.0 up to 36.7 Provitamin A Carotenoid levels (ug/g)



# Golden Rice is now a breeding project

# Transferring Golden Rice traits into popular rice varieties at IRRI



IR64 & IR36: Mega-varieties with broad Asian coverage (GR1 & GR2)

BR29: The most popular and productive *boro* rice variety in **Bangladesh** (GR1 & GR2)

An IRRI-bred line released as PSB Rc82: the most popular rice variety in the **Philippines** (GR2)

Only one event will ever be released/go through full regulatory approval; **2011 first release** 

Parallel introgression breeding being done by Golden Rice Network partners in India, Vietnam, and the Philippines



#### **Transplanting at IRRI April 2, 2008**

### First Outdoor Trial of Golden Rice in Asia

IR64 GR1 event 309; 20 lines

#### May 30, 2008



TITLE

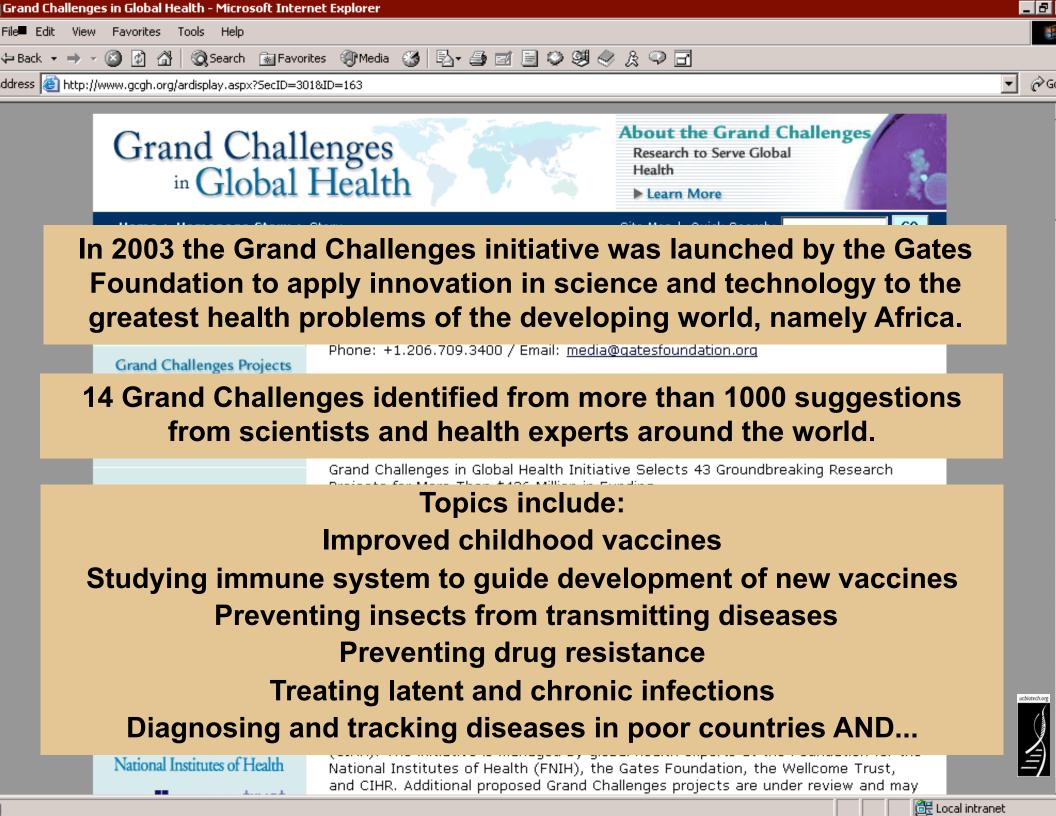
E. Boncodin, Fedl Budget Secy Manila Philippines

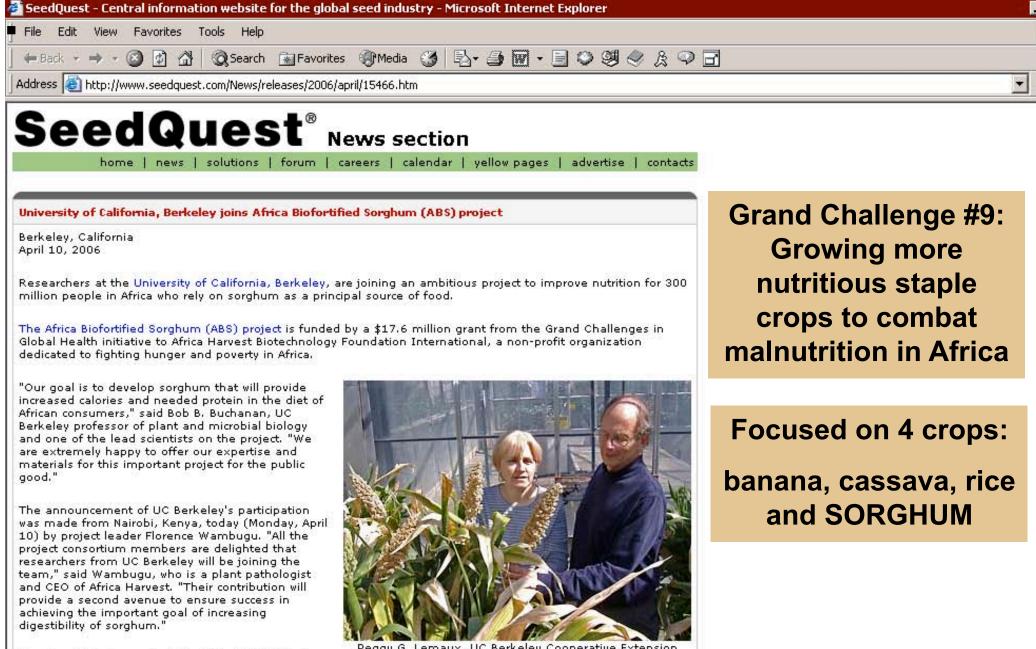
April 10, 2008



#### Public-Private sector partnership: Development of SuperSorghum







The Grand Challenges in Global Health initiative is supporting nutritional improvement of four staple crops - sorghum, cassava, bananas and rice - as one of its 14 "grand challenges" projects that focus on using science and technology to dramatically

Peggy G. Lemaux, UC Berkeley Cooperative Extension specialist in plant and microbial biology, and Bob Buchanan, professor of plant and microbial biology, inspect sorghum plants in a controlled temperature growth room. (Rosemary Alonso photo)

improve health in the world's poorest countries. The initiative is funded by the Bill & Melinda Gates Foundation, the Wellcome Trust, and the Canadian Institutes of Health Research.

In June 2005, the initiative awarded \$16.94 million to Africa Harvest to head a consortium of public and private research institutes for the ABS project. The Gates Foundation has just supplemented this amount with \$627,932 to fund the work of Buchanan and correspondences Ready & Longov, UC Bockeley, Cooperative Extension specialist

# Why Pick Sorghum for Our Target?

- Fifth most important food grain worldwide
- 90% grown in Africa and Asia in arid and semiarid regions

Cultivated sorghum

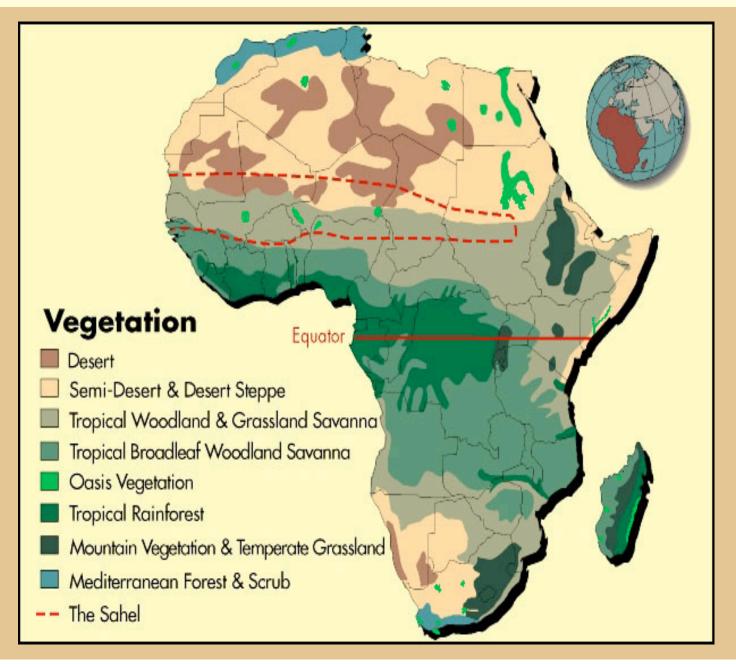
Wild outcrossing species



Staple food for 300
 million in Africa



#### Sorghum is uniquely adapted to Africa's climate – it withstands both drought and water logging





Only region where poverty and hunger both continue to increase. In the past 15 years number of Africans living on less than \$1 per day increased to 50%.

Nearly 33% of all men, women and children in sub-Saharan Africa are currently undernourished compared with 17% in the developed world.

Africa's farms yielded 19% less agricultural production per capita in 2005 than they did in 1970!

Gaborone Rretoria

In 2004 UN Development Programme said Africa as a whole would not reach its 2015 Millennium Development Goal for alleviating human poverty until 2147!



From "Starved for Science: How Biotechnology Is Being Kept out of Africa" by R. Paarlberg 2008

Sorghum is a major food in these areas but is nutritionally deficient in: **Vitamins Minerals** Amino acids (like most cereals) But, uniquely, it is **Poorly Digested** 

Can't they just eat something else to make up for deficiencies?





# Addressing the nutritional challenge

### **Goal of Super Sorghum Project**

Develop more nutritious, easily digestible, biofortified sorghum, containing higher levels of pro-vitamin A, vitamin E, iron, zinc, and deficient amino acids, lysine, tryptophan and threonine, for the arid and semi-arid tropical areas of Africa

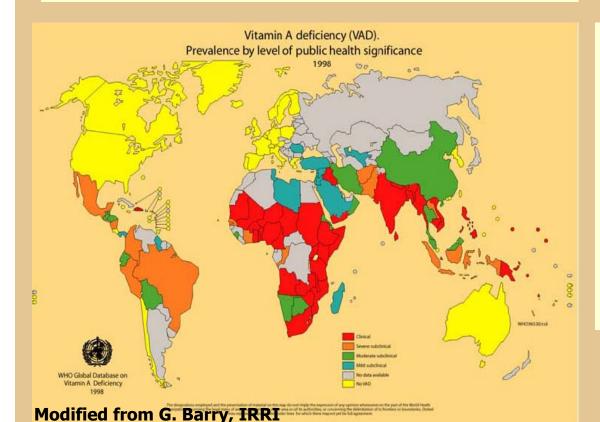
### **Focus of ABS Project: Food Quality**

Earlier breeding efforts to improve some target traits were unsuccessful GE strategy needed to improve multiple target traits simultaneously All genes from crop sources, except one from common microbe All approaches validated in corn and other cereals





#### Vitamin A Deficiency: Severe Health Problem in Africa



- Sorghum grain very low levels of Vit A and E
- Vit A critical for eyesight Vit E protects Vit A.
- Increase production by improving rate-limiting steps in biosynthesis

**/it.A** 

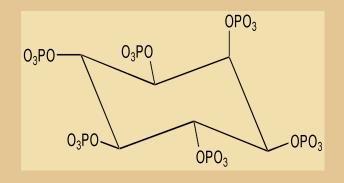
it. E

# ABS Project Produces First Golden Sorghum in 2009





## Improving Iron and Zinc Availability in Sorghum by Reducing Phytic Acid in Grain



# **Phytic Acid**

- Phytic acid in the seed binds iron and zinc
- Reduce phytic acid by blocking production
- Lower phytic acid frees iron & zinc to be taken up from food



### Improving Protein Quality UCB involvement

#### Improve Protein Quality

- Introduce new protein with increased Lys, Trp, Met, Thr
- Decrease proteins with poor quality

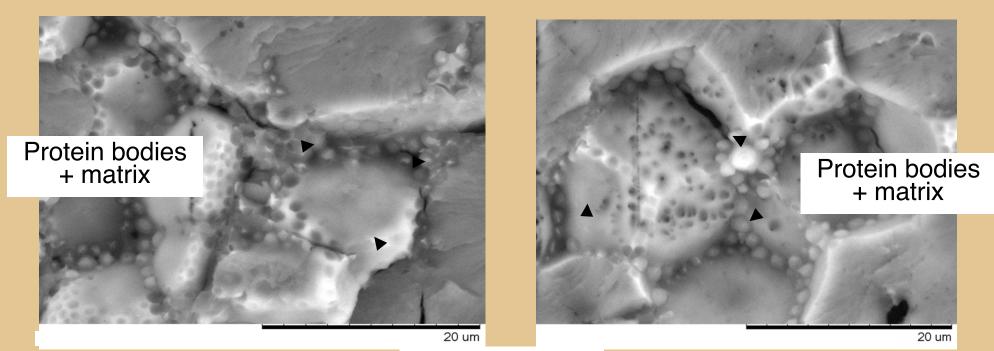
#### Improve Protein Digestibility

- Decrease proteins negatively affecting digestibility
- Alter digestibility of protein



## **Improving Digestibility**

#### Starch granules embedded in protein matrix



Starch granules

Disulfide bonds within and between kafirins hinder starch and storage protein digestibility upon cooking



# **Super Sorghum**

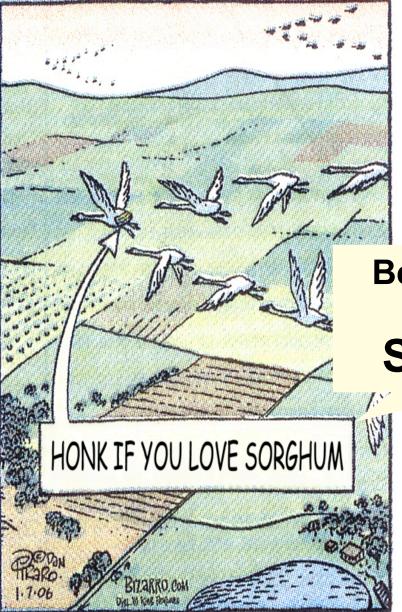


# NO MAGIC BULLET

# But it can help!



BIZARRO Piraro



#### Because we love SUPER SORGHUM!



San Francisco Chronicle (modified)