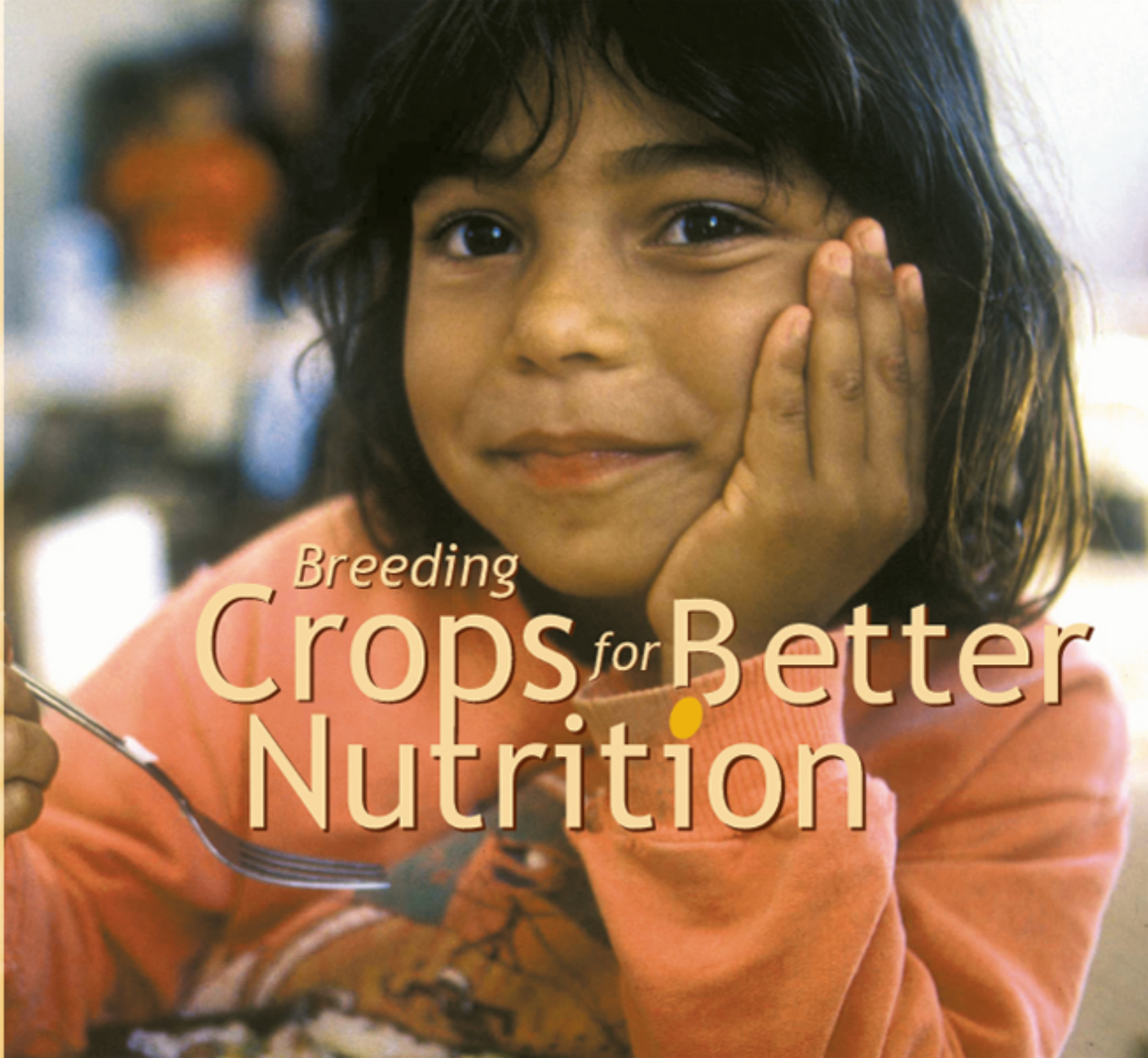

Breeding Crops for Better Nutrition

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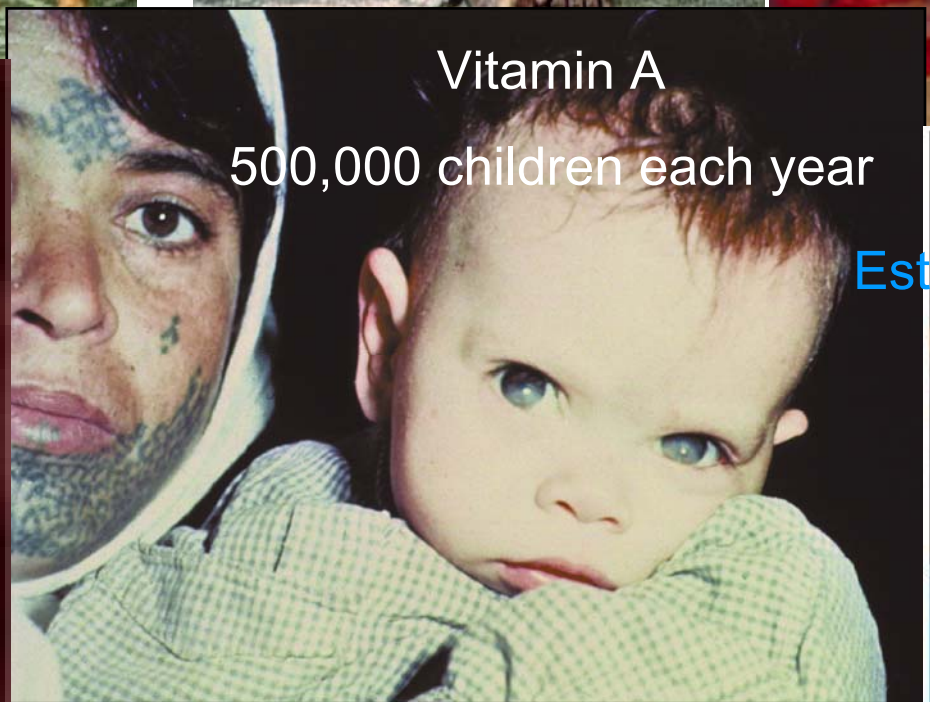
A Massive Problem

Zinc

Estimated 2 billi

Iron

Estimated 2 billion



Vitamin A

500,000 children each year

Iodine

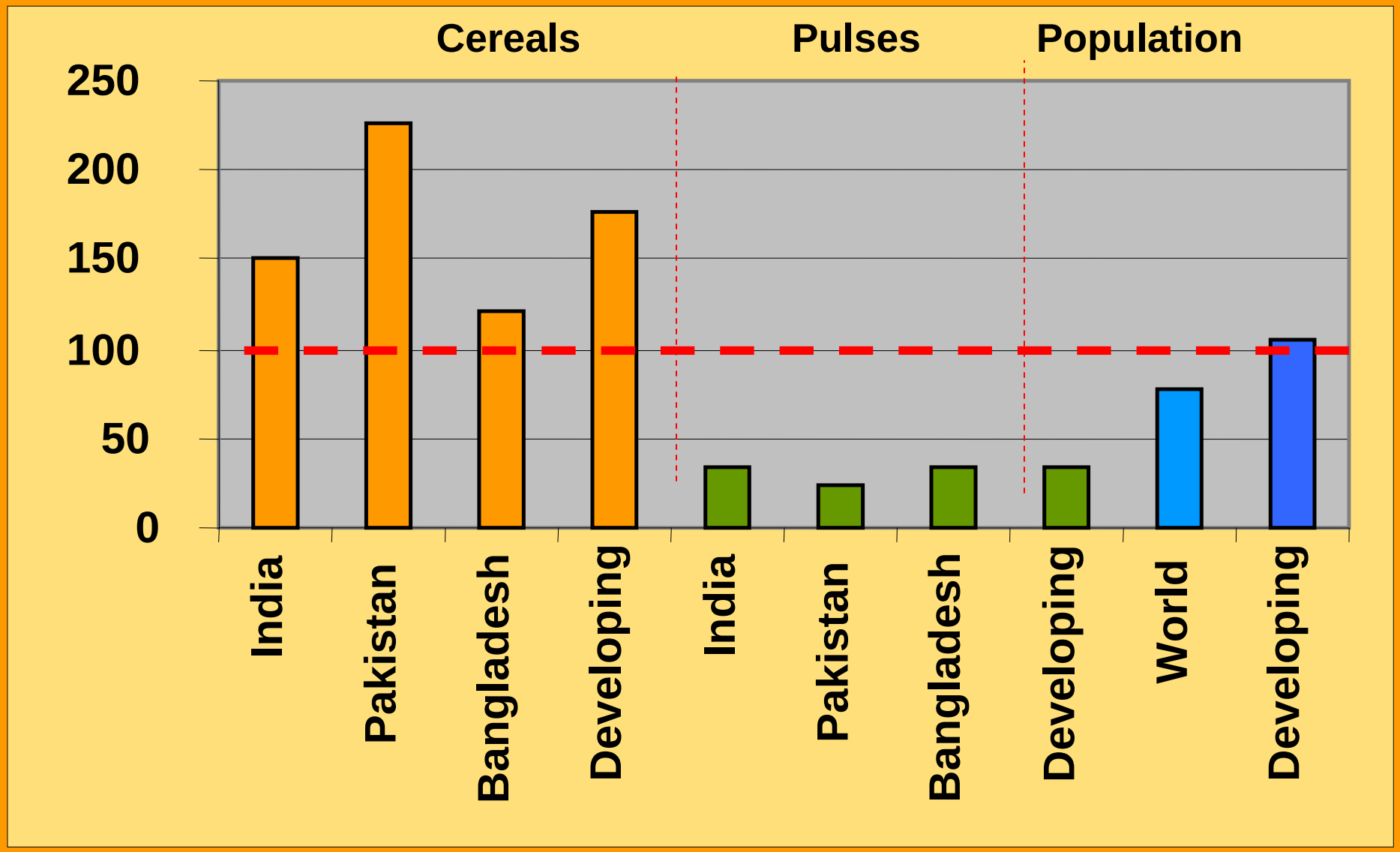
Estimated 1.5 billi

Consequences of Micronutrient Malnutrition

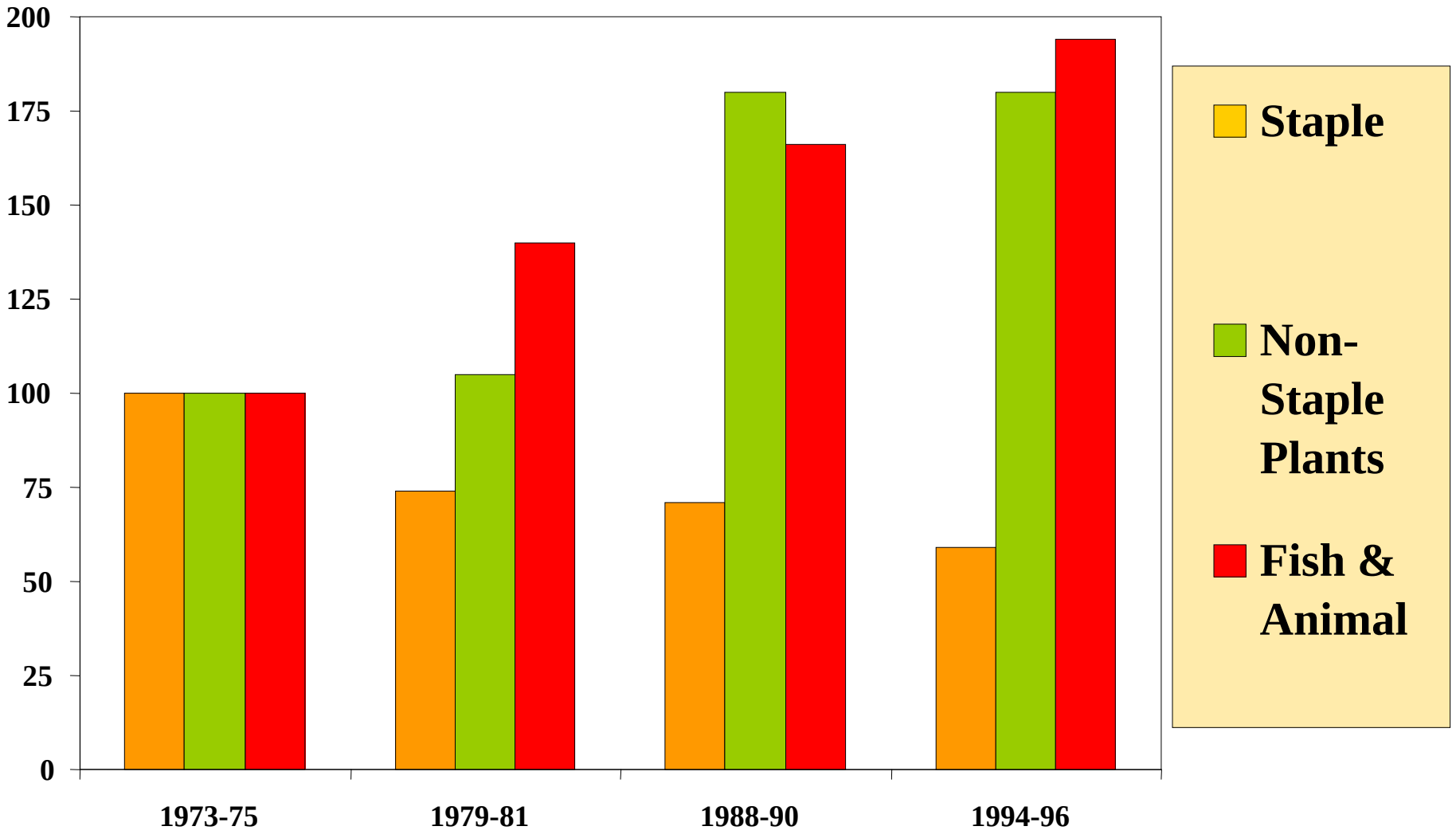
- higher morbidity
- higher mortality
  - 23% reduction with vitamin A supplementation
- lower cognitive ability
- lower work productivity
- impaired growth
- impaired reproduction
- 5% annual loss in GDP in South Asia

HarvestPlus

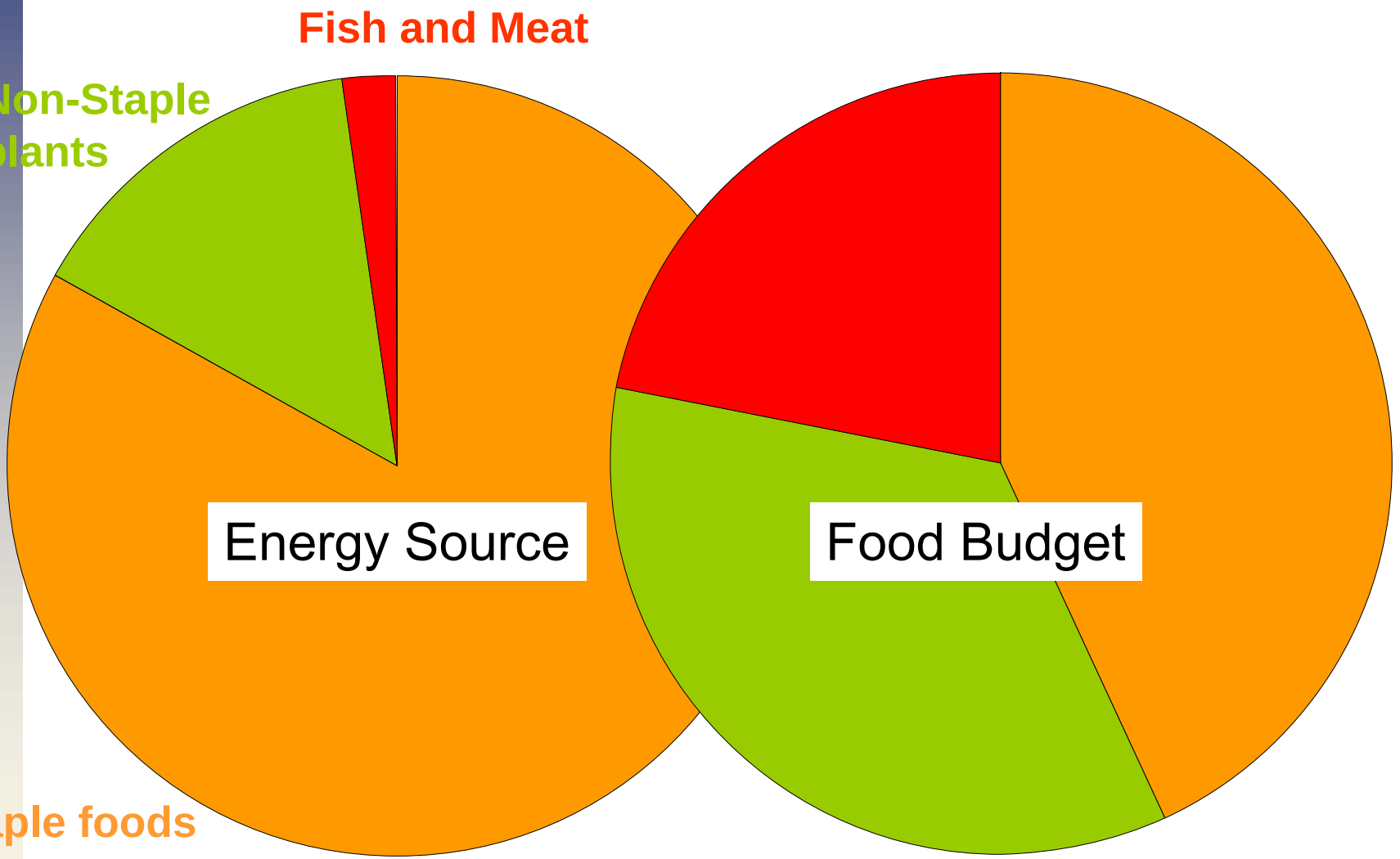
% Changes in Cereal & Pulse Production & in Population Between 1965 & 1999



Indices of Inflation-adjusted Prices for Bangladesh
1973-75 = 100

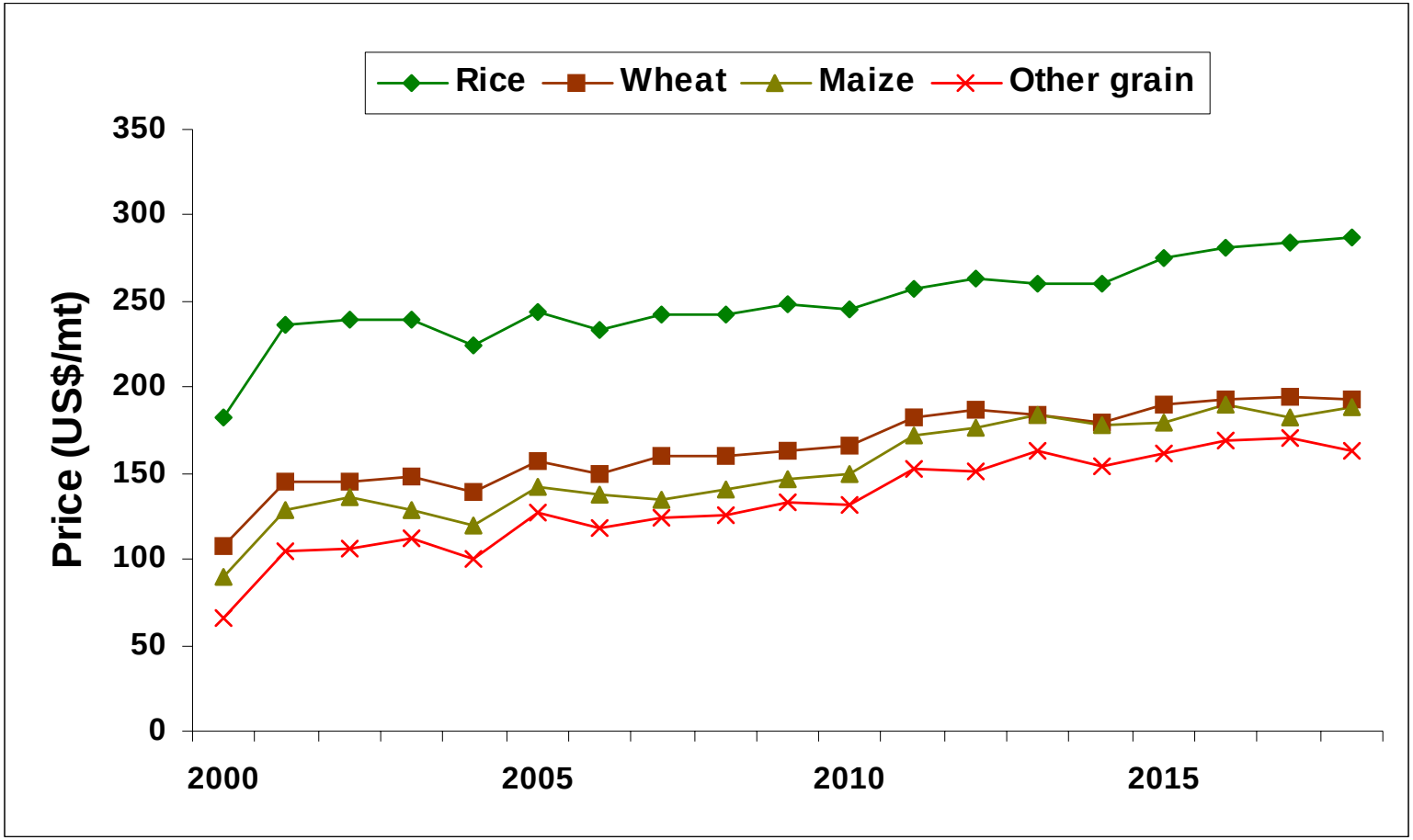


Share of Energy Source & Food Budget in Rural Bangladesh



Rising Food Staple Prices

Real world cereal prices projected to rise



Source: M. Rosegrant, IFPRI 2007

Calcium Deficiency in Bangladesh

Global Warming

Climate Change and Nutrients in Plants

- Increased Co_2 levels will generally lead to higher yields offsetting some of the negative impacts (higher temp, drought), but will result in **lower nutritional quality**

- Protein and micronutrient levels likely to drop (both metabolic processes and nutrient uptake at roots affected)

Source: Nature, Vol. 448, August 2007

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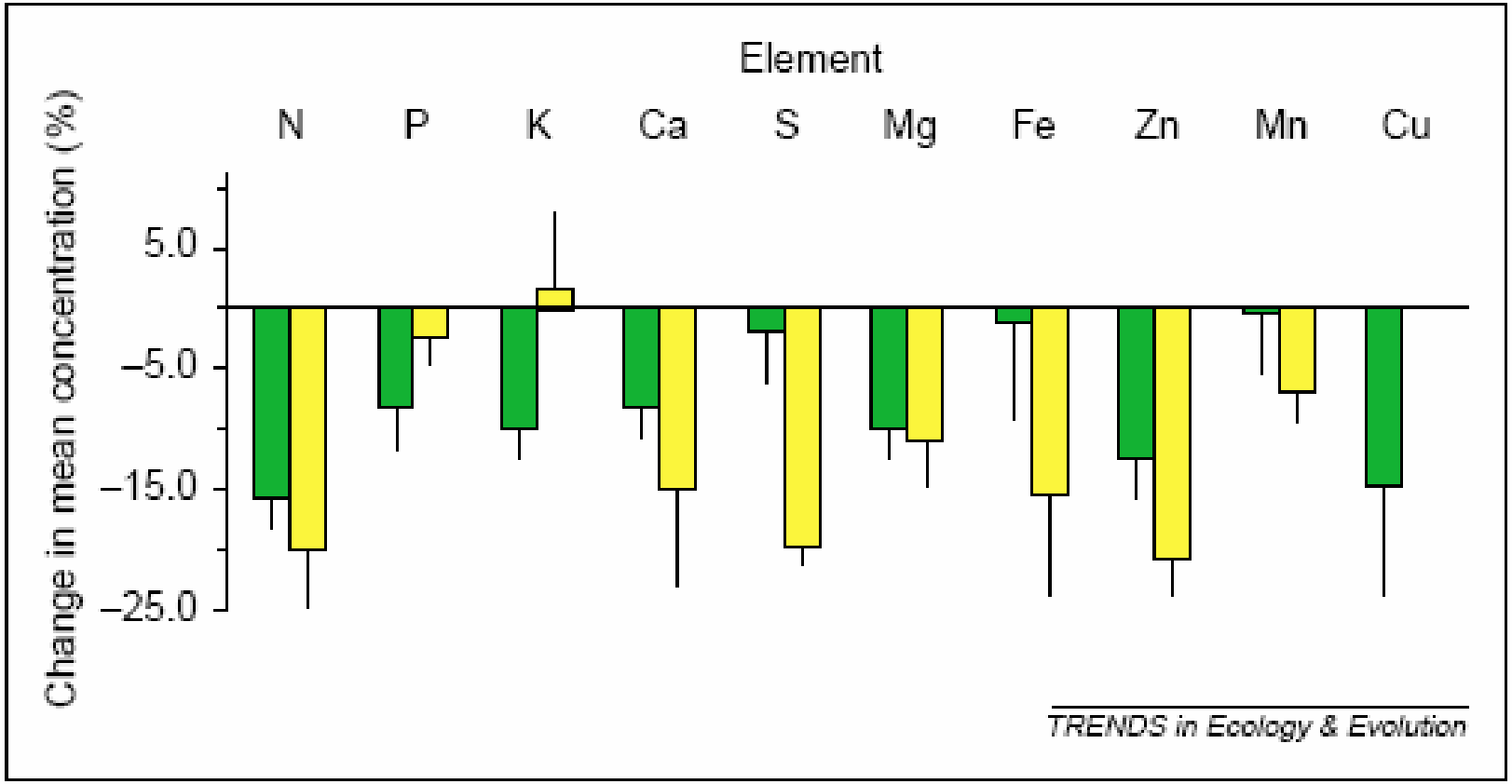
Changes (%) in the mean concentration of essential elements in plants grown in twice-ambient atmospheric CO_2 relative to those grown at ambient levels



TRENDS in Ecology & Evolution Vol.17 No.10 October 2002

All foliar plants

wheat

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Biofortification Strategy

Breed micronutrient dense staple crops with higher levels of vitamin A, iron, and zinc that will improve human nutritional status when eaten.

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Niche/Advantages of Biofortification

- **Cost-effective**; research at a central location can be multiplied across countries and time
- **Sustainable**; investments are front-loaded, low recurrent costs
- **Targets the poor** who eat high levels of food staples
- **Rural-based**; complements fortification and supplementation

HarvestPlus

Consultative Group on Int'l Agricultural Research

Partners with HarvestPlus

Funding ($million for 2003-2008)

Gates Foundation	$38.7
World Bank	$13.5
USAID	$6.9
DFID	$3.7
DANIDA & SIDA	$1.9
Asian Development Bank	$0.5
Interest	$1.2
TOTAL	$66.5

Will Biofortification Work?

- Can breeding be successful, can nutrient levels be increased to high enough levels?
- Will the extra nutrients be absorbed at sufficient levels that micronutrient status will be improved?
- Will farmers adopt and will consumers buy/eat in sufficient quantities?

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HarvestPlus Milestones By Crop – Year 4 of 10

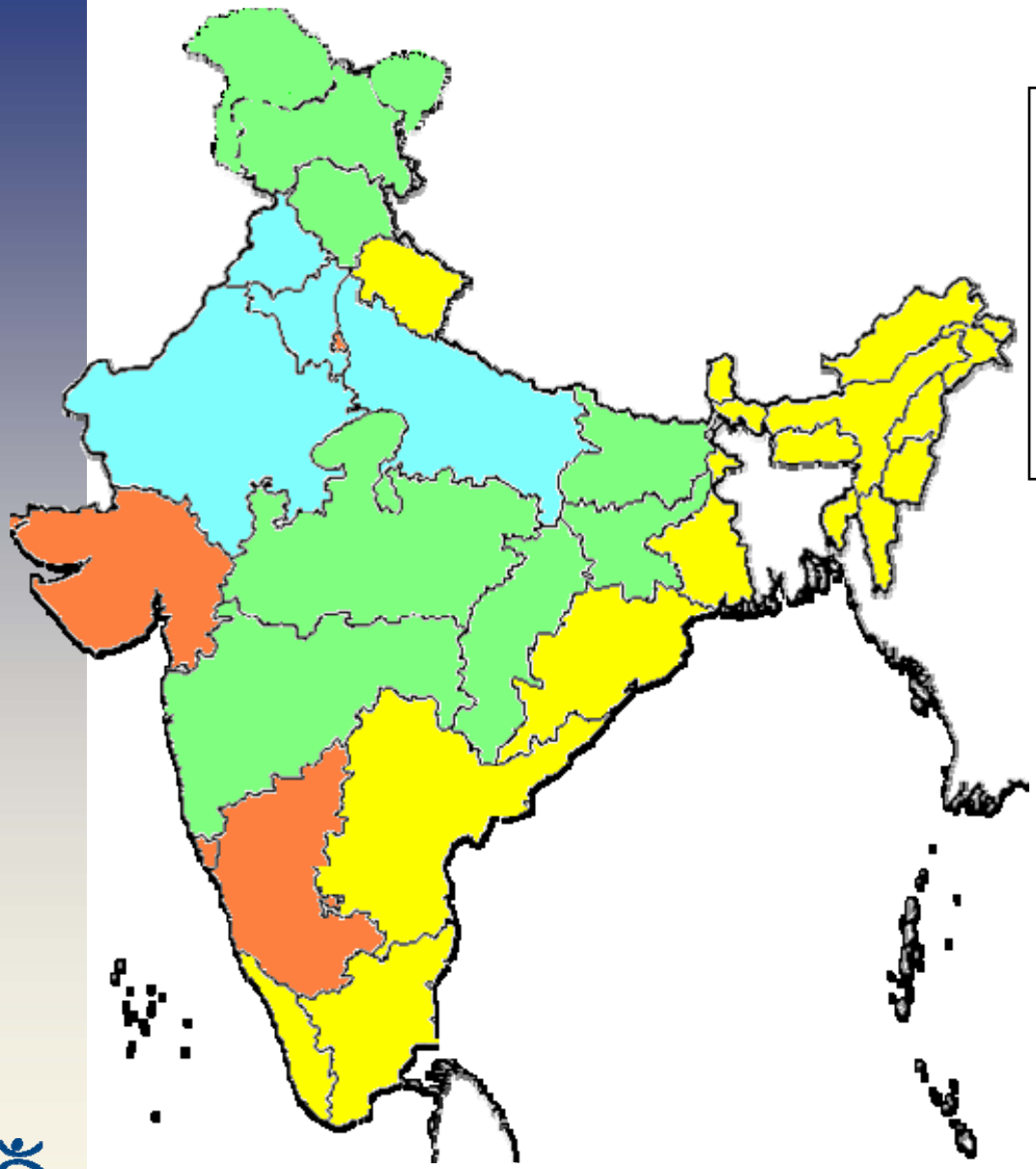
Step	SwPo	Bean	Rice	Wheat	Maize	Cass
1. Breeding						
2. Bioavail-ability						
3. End User						

Schedule of Product Releases

Crop	Nutrients	Release Year of Initial Lines*
Sweetpotato	Pro-vitamin A	2007
Bean	Iron, Zinc	2010
Pearl Millet	Iron, Zinc	2011
Rice	Zinc, Iron	2012
Maize	Pro-vitamin A, Zinc, Iron	2013
Wheat	Zinc, Iron	2013
Cassava	Pro-vitamin A	2014

* Approved for release by national governments after 2-3 years of testing

Consumption of Staple Foods in India



"High consumption:"
> 325 grams dry, milled rice, wheat, rice+wheat per capita per day;
74% rural; 26% urban

Legend:

- High rice consumption (32% of population)
- High wheat consumption (27% of population)
- High wheat plus rice consumption (30%)
- Relatively low wheat plus rice consumption (11%)

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India Dissemination Strategy

- Incur breeding costs such that genes that determine high iron and zinc content are included in all major breeding lines → **all crosses will contain high iron and zinc** → released lines with agronomic superiority will contain high iron and zinc
- Over time, rice and wheat production will contain ever higher levels of iron and zinc as non-biofortified varieties are replaced.

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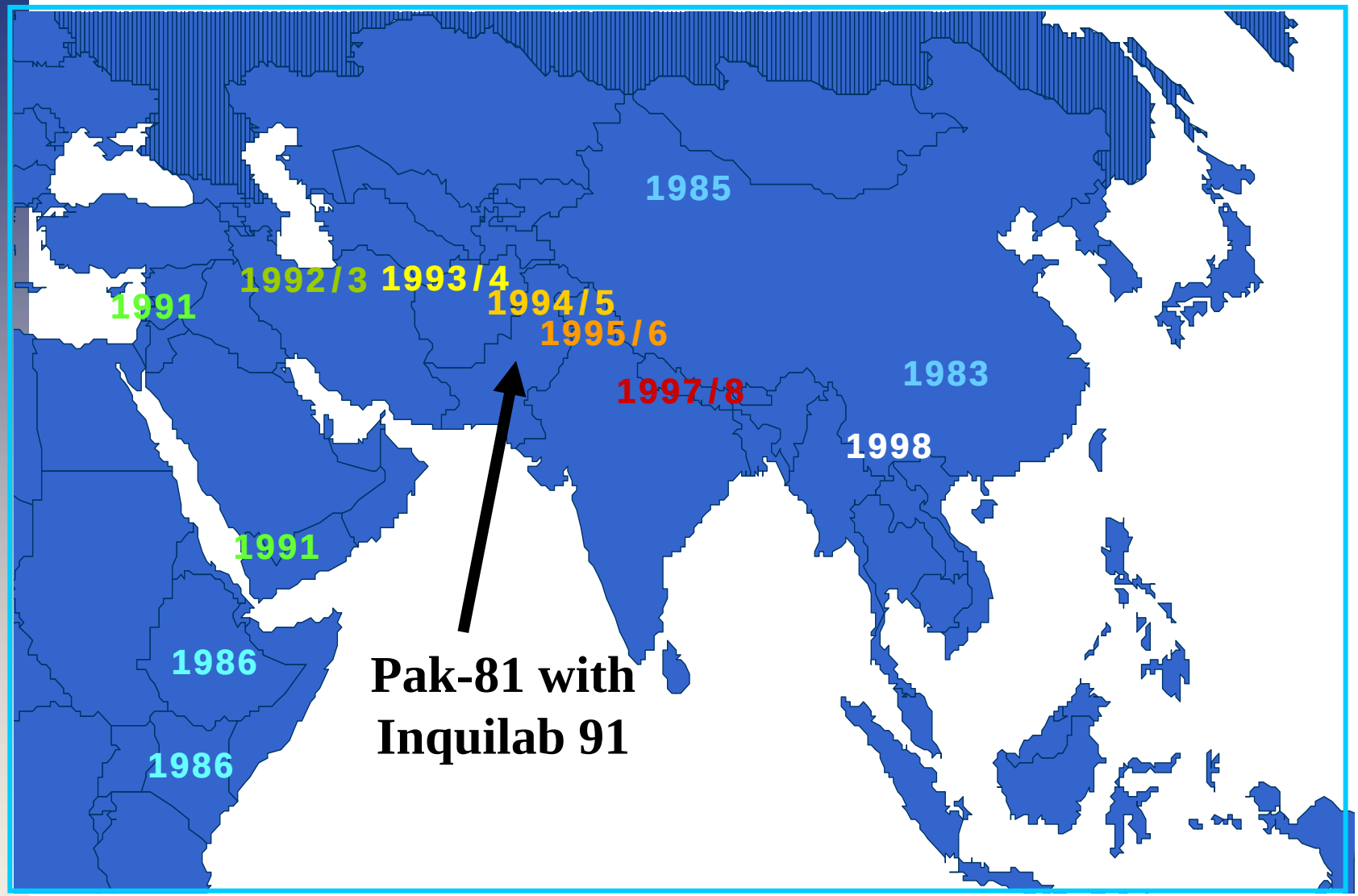
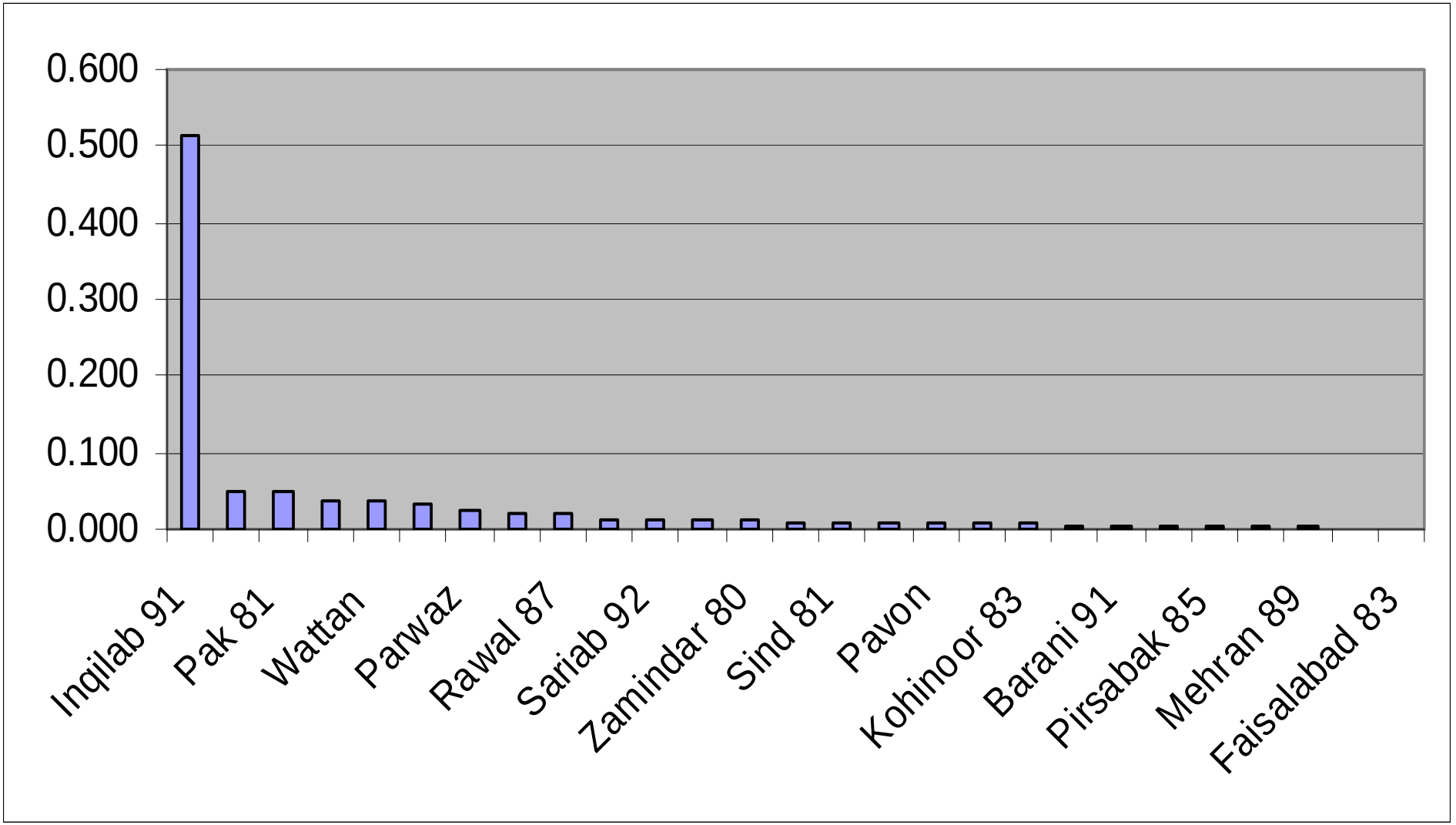


Movement of *Yr9* Virulence

Pakistan Variety Area Share, 1997



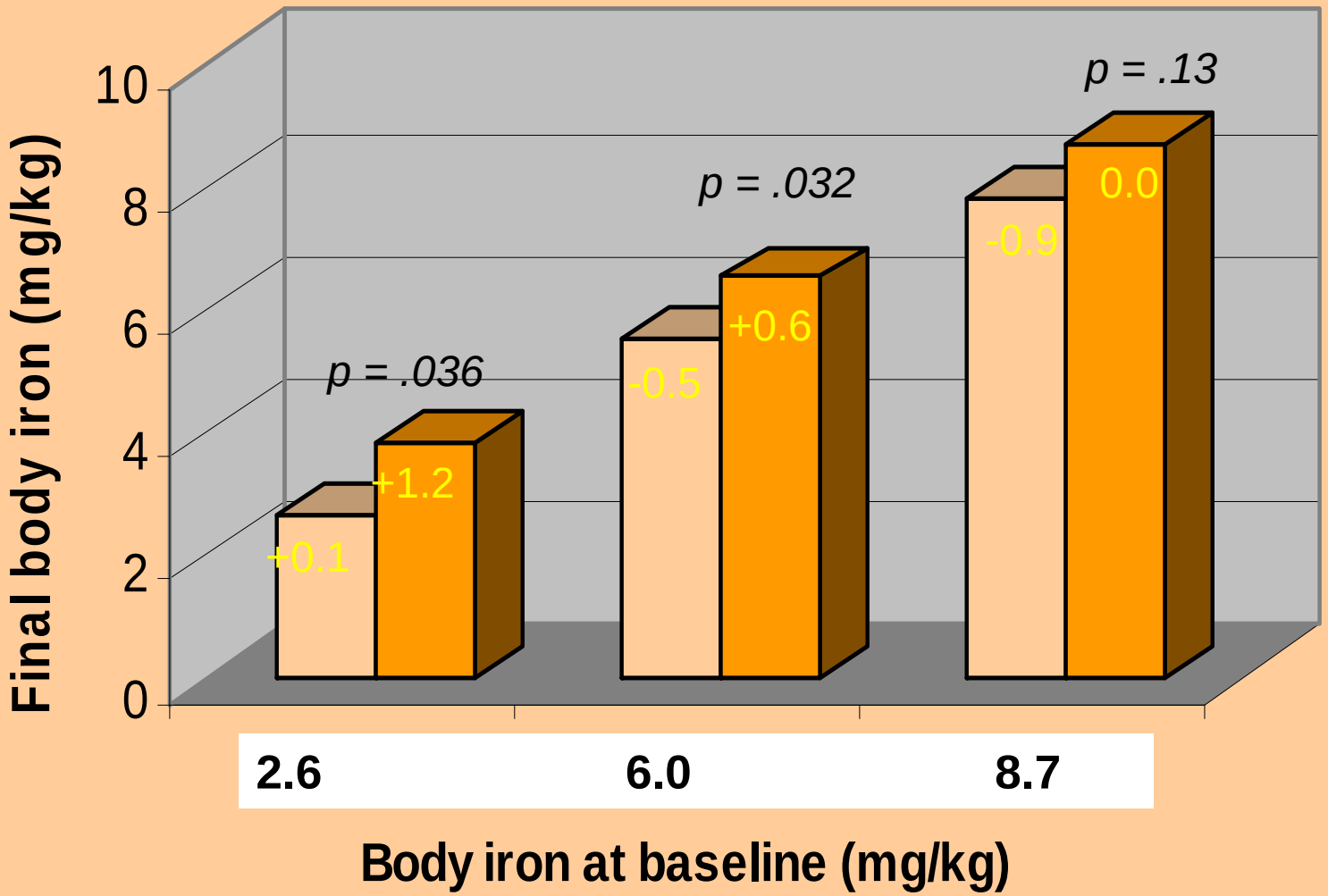
Source: CIMMYT Database

Pakistan, Peshawar

The Subjects

Religious sisters from 10 convents

Total body iron nine months after consuming high-iron or control rice (n=137)



From Haas, Beard, Murray-Kolb, del Mundo, Felix and Gregorio, 2004

In Conclusion …

"Such intimately related subjects as agriculture, food, nutrition and health have become split up into innumerable rigid and self-contained little units, each in the hands of some group of specialists. The experts, as their studies become concentrated on smaller and smaller fragments, soon find themselves … learning more and more about less and less. Everywhere knowledge increases at the expense of understanding …"

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In Conclusion

"The remedy is to look at the whole field covered by crop production, animal husbandry, food, nutrition, and health as one related subject and then to realize the great principle that the birthright of every crop, every animal, and every human being is health."

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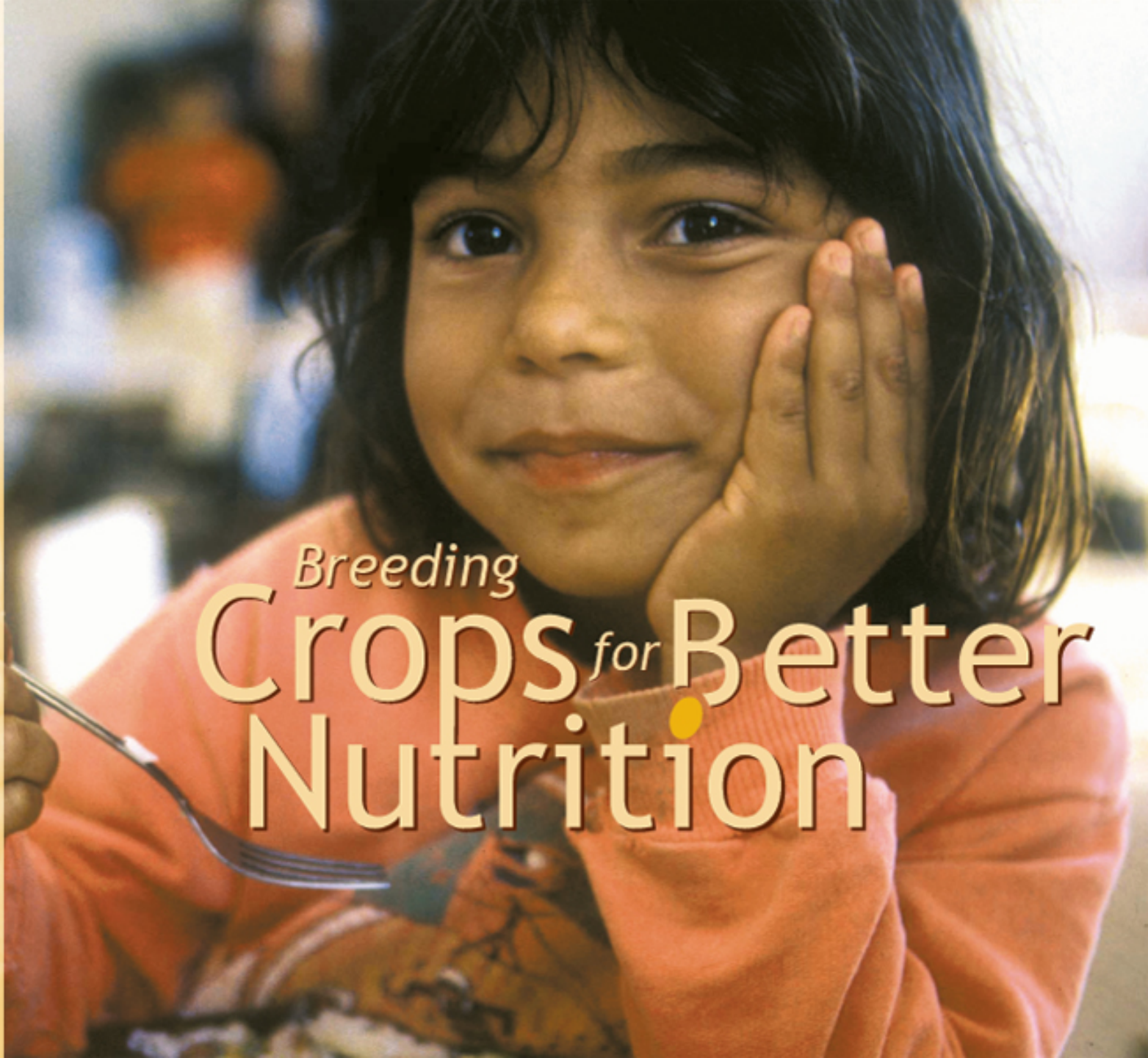
The Soil and Health, 1945

Sir Albert Howard,
1873-1947



Breeding Crops for Better Nutrition

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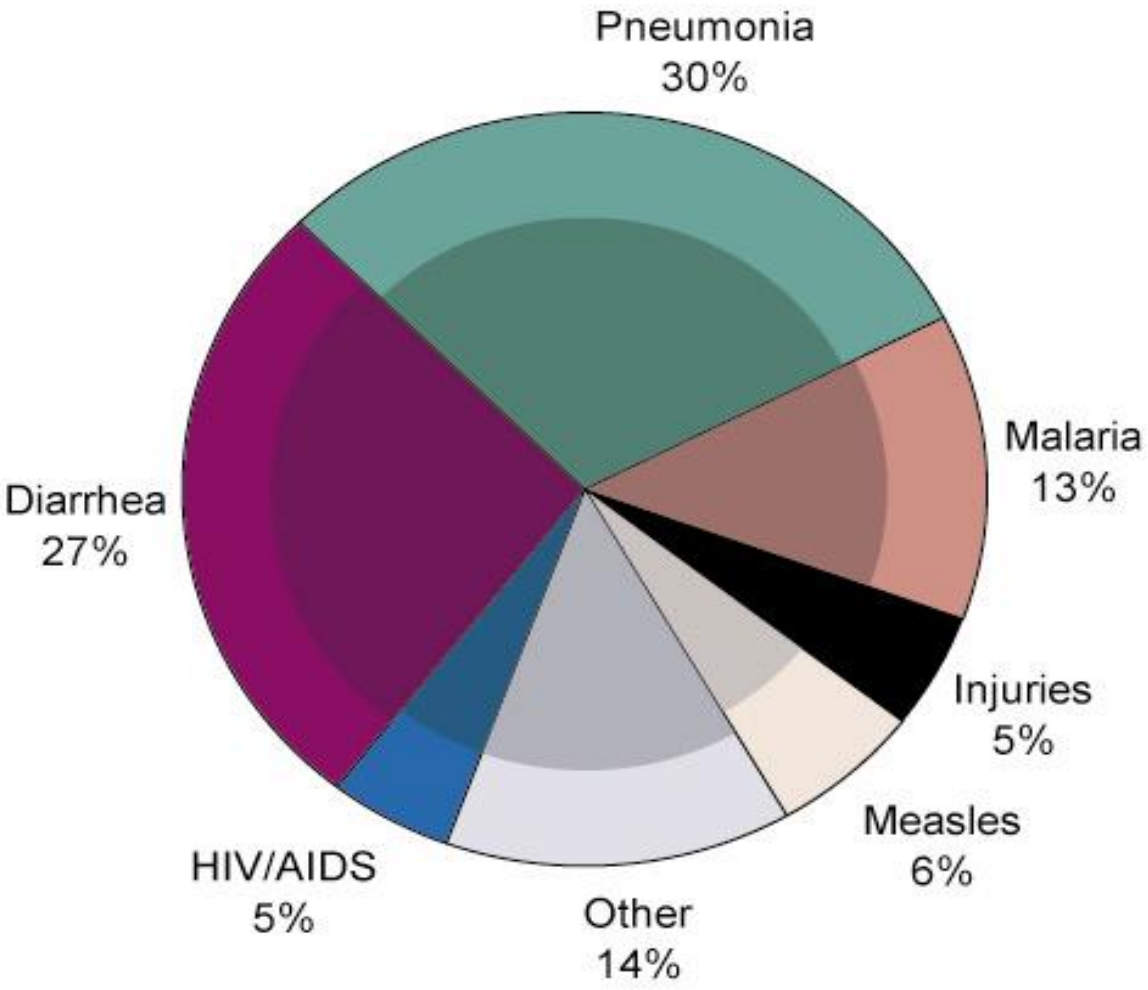
How Important is Nutrition for Health?

Undernutrition's impact on post neonatal child deaths by illness

53 % of all deaths are directly caused by undernutrition in diseased children

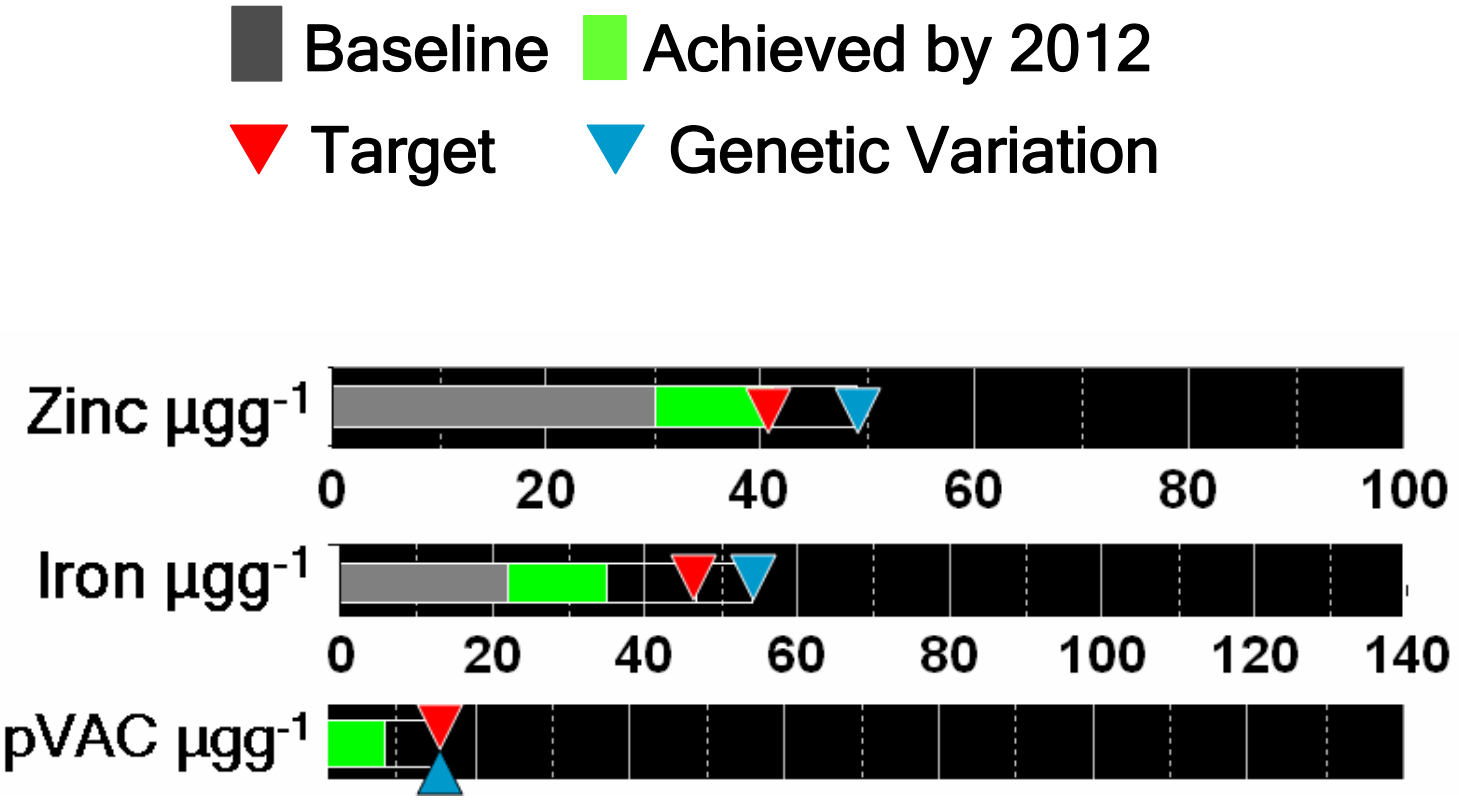


J.P. Habicht, Cornell University 2008

HarvestPlus: Coordinating a Multidisciplinary Program

Function	Rice IRRI	Maize CIMMYT	Wheat CIMMYT	Cassava CIAT	Sweet potato CIP	Bean CIAT
1. Breeding						
2. Biotechnology						
3. Food processing						
4. Human nutrition						
5. Reaching end-users						
6. Impact/policy						
7. Communication						

Maize


Baseline
Achieved by 2012
Target
Genetic Variation
Zinc µgg-1
0
20
40
60
80
100
Iron µgg-1
0
20
40
60
80
100
120
140
pVAC µgg-1

Maize Crop Meeting
Zambia, March 2007

16 Breeders attended from the following countries:

Mexico	Brazil
Ethiopia	Ghana
Guatemala	Zambia
Zimbabwe	Mozambique
Angola	China
Nigeria	South Africa

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HarvestPlus: Coordinating a Multidisciplinary Program

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1. Breeding						
2. Biotechnology						
3. Food processing						
4. Human nutrition						
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6. Impact/policy						
7. Communication						

There is Considerable Natural Variation in Maize for Flux Into the Carotenoid Pathway

"Natural Genetic Variation in Lycopene Epsilon Cyclase Tapped for Maize Biofortification"
Science, January 18, 2008

We show that variation at the lycopene epsilon cyclase locus (lcyE) alters flux down a-carotene versus b-carotene branches of the carotenoid pathway.

Selection of favorable **lcyE alleles** with inexpensive molecular markers will now enable developing country breeders to more effectively produce maize grain with higher provitamin A levels.

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Carotenoid Biosynthetic Pathway

Synthase

PSY *y1*

GGPP

Phytoene

2x **PDS** *vp5*

Phytofluene

*

ζ- carotene

2x **ZDS** *vp9*

Neurosporene

Desaturases

Lycopene

Cyclases

β- LCY

e- LCY

*

β- LCY

α- carotene

β-carotene

*

*

β-crytptoxanthin

*

Lutein

Zeaxanthin

Hydroxylases

HarvestPlus: Coordinating a Multidisciplinary Program

Function	Rice IRRI	Maize CIMMYT	Wheat CIMMYT	Cassava CIAT	Sweet potato CIP	Bean CIAT
1. Breeding						
2. Biotechnology						
3. Food processing						
4. Human nutrition						
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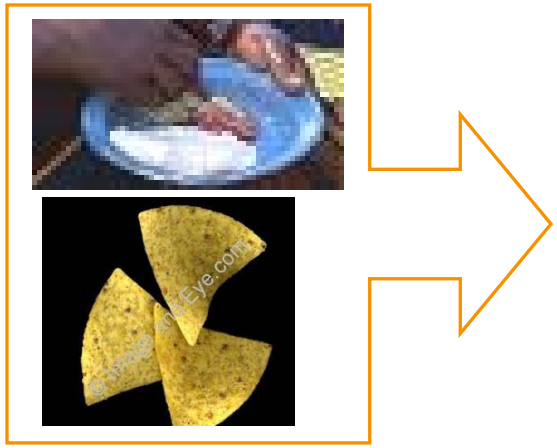
6. Impact/policy						
7. Communication						

Yellow/orange maize is highly promising to improve vitamin A status



A reasonable amount of pro-vitamin A is retained after processing

i. Mostly concentrated in the endosperm, therefore not lost by milling

ii. Majority is retained in cooked maize products typical for East/West Africa and Central America

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Maize – high pro-vitamin A retention

	Retention after processing
Wet milled	90-93%
Unfermented porridge	75%
Fermented porridge	71-75%
Tortilla chips	64%

HarvestPlus: Coordinating a Multidisciplinary Program

Function	Rice IRRI	Maize CIMMYT	Wheat CIMMYT	Cassava CIAT	Sweet potato CIP	Bean CIAT
1. Breeding						
2. Biotechnology						
3. Food processing						
4. Human nutrition						
5. Reaching end-users						
6. Impact/policy						
7. Communication						

Yellow/orange maize is highly promising to improve vitamin A status

'Pro-Vitamin A from orange maize has a high rate of Vitamin A activity'

	Average for plant foods	Orange maize (gerbils)	Orange maize (humans)
Beta-carotene	12 BC = 1 retinol	~3 BC = 1 retinol	~ 7 BC = 1 retinol

Preliminary

Yellow/orange maize is highly promising to improve vitamin A status

Next steps...

Select target country

Bioefficacy

Produce maize

HarvestPlus: Coordinating a Multidisciplinary Program

Function	Rice IRRI	Maize CIMMYT	Wheat CIMMYT	Cassava CIAT	Sweet potato CIP	Bean CIAT
1. Breeding						
2. Biotechnology						
3. Food processing						
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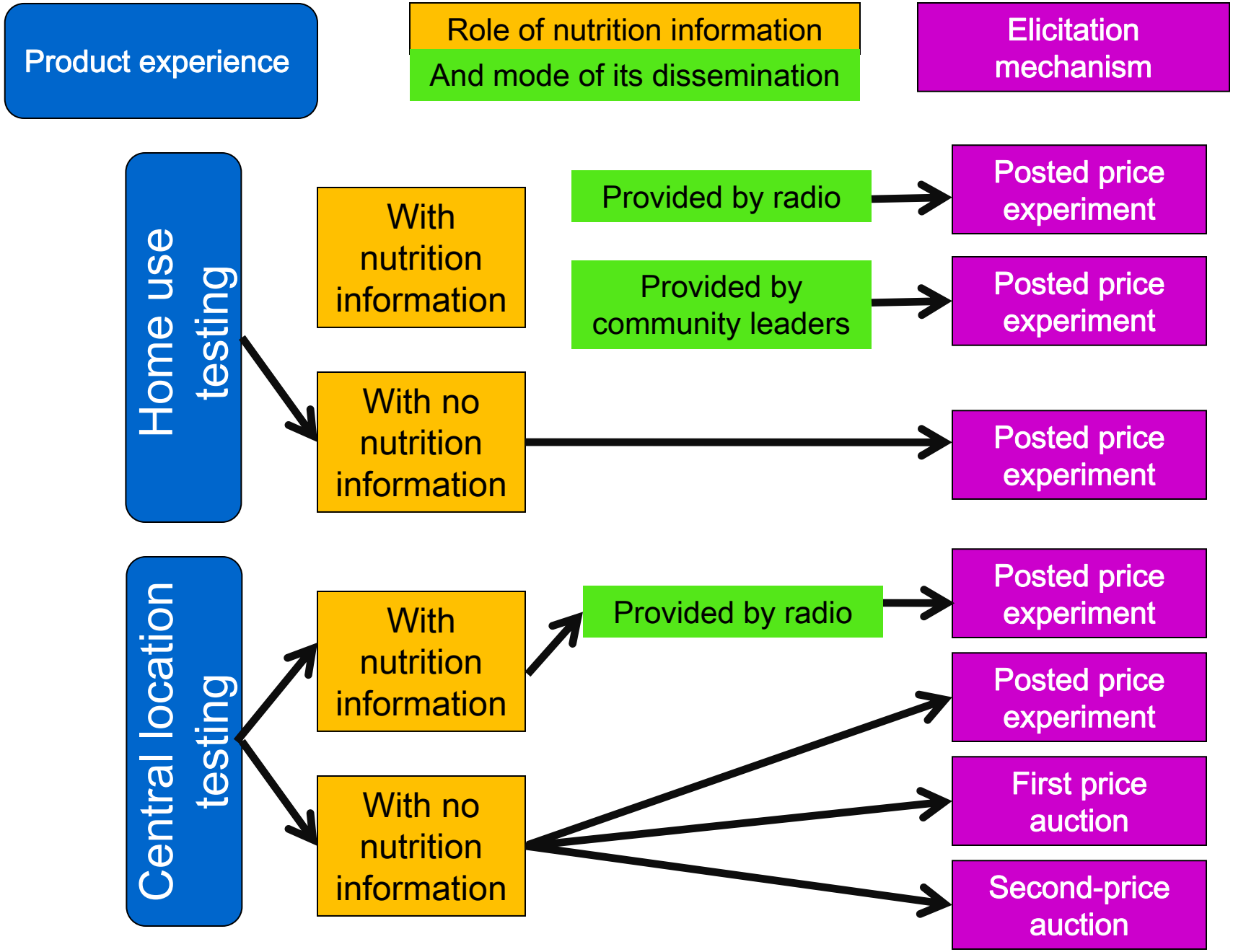
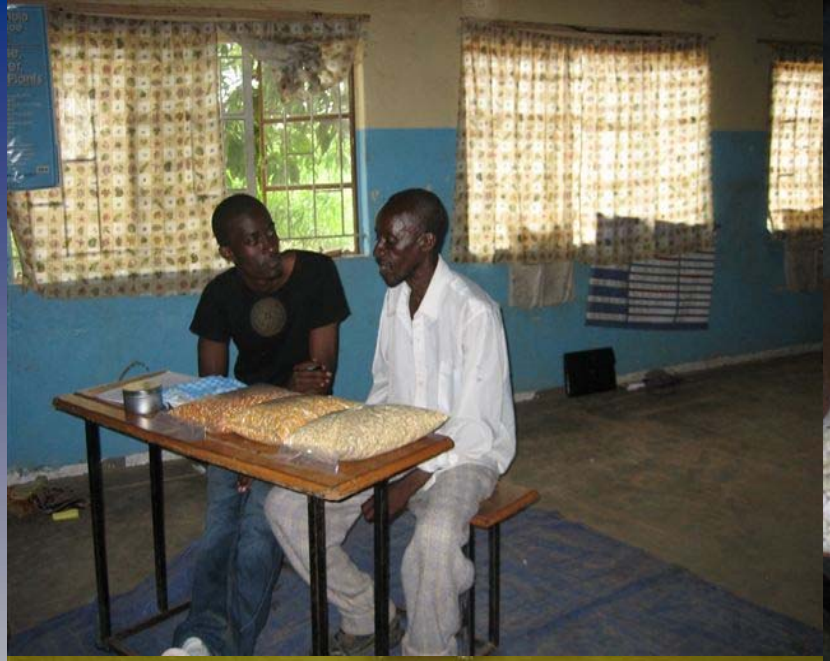

Product experience
Role of nutrition information
And mode of its dissemination
Elicitation mechanism
Home use testing
With nutrition information
Provided by radio
Posted price experiment
Provided by community leaders
Posted price experiment
With no nutrition information
Posted price experiment
Central location testing
With nutrition information
Provided by radio
Posted price experiment
Posted price experiment
With no nutrition information
First price auction
Second-price auction



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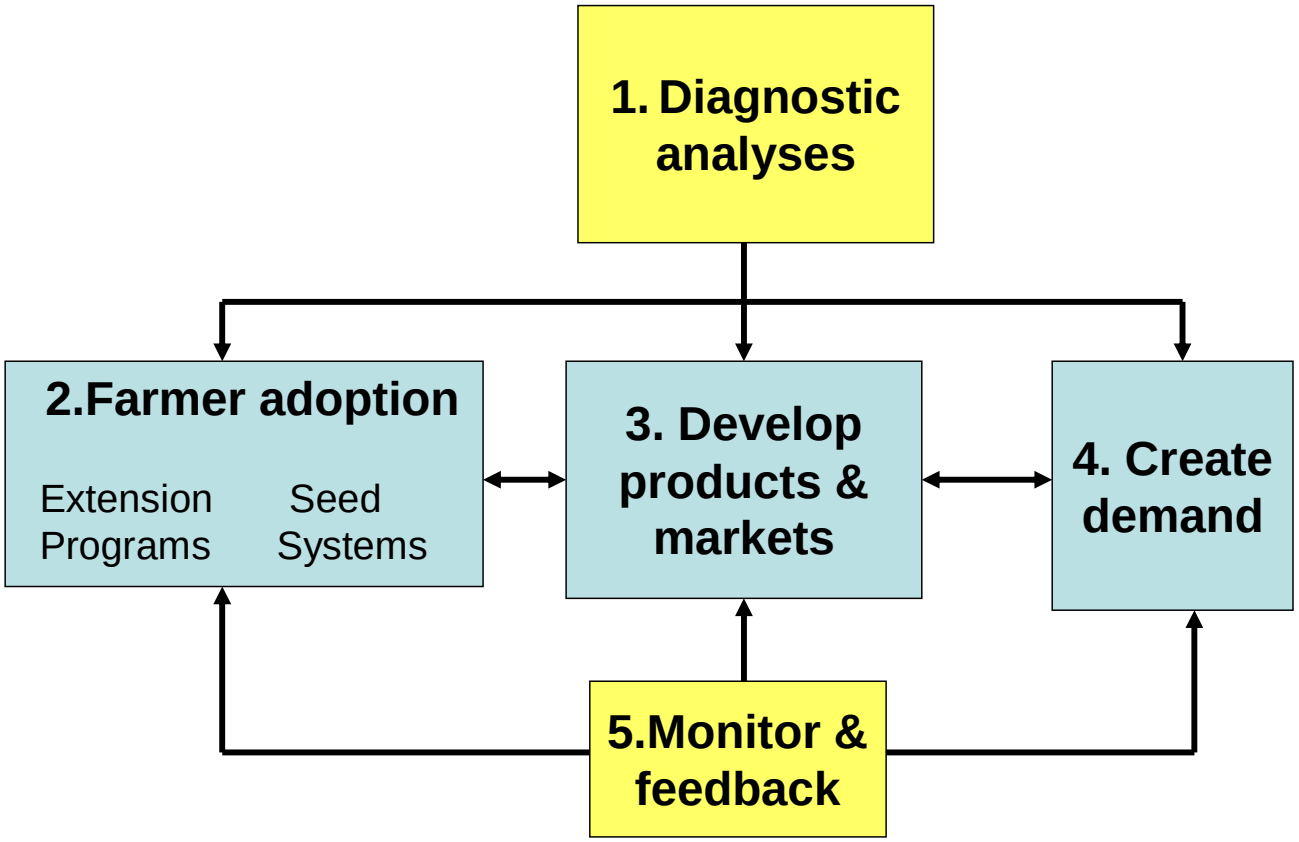
Orange Fleshed Sweetpotato

Reaching End Users



Towards Sustainable Nutrition Improvement in Rural Mozambique (TSNI), Project Activities April - September 2004

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Taste tests are conducted at every adaptive trial harvest to determine taste and appearance preferences of local consumers.

Towards Sustainable Nutrition Improvement in Rural Mozambique (TSNI), Project Activities April - September 2004

Sweet potato bread maker Carlitos Agosto making his bread at home and selling it in the nearby market of Lualua. Bread is marketing under the name of *Pão de Ouro* (Golden Bread). Carlitos almost doubles his profit substituting 38% of wheat flour (by weight) with boiled and mashed sweet potato.

Towards Sustainable Nutrition Improvement in Rural Mozambique (TSNI), Project Activities April - September 2004

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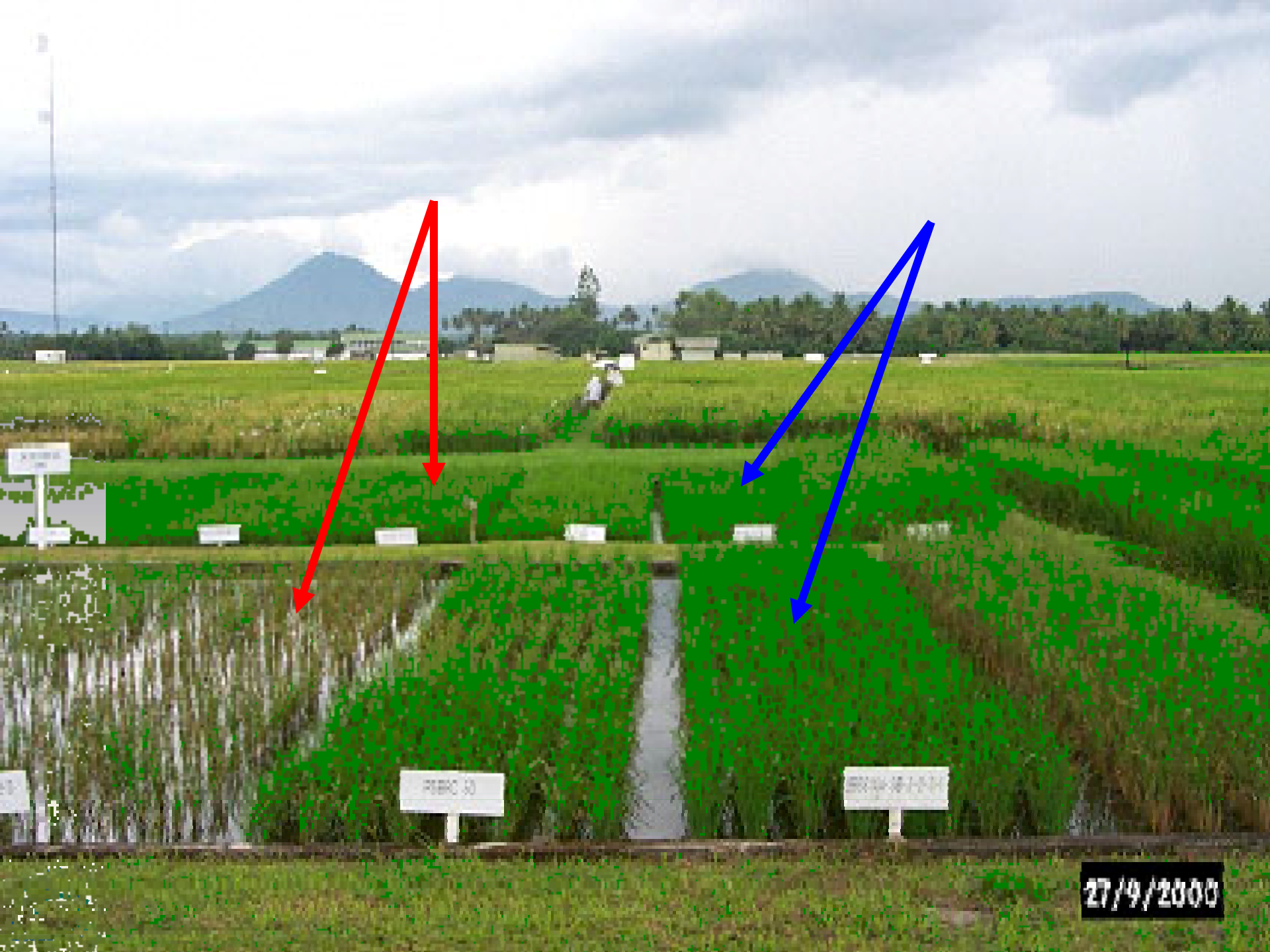
Local theater group in Malei locality presenting scene where a herbalist is providing roots to mix in water to give to the newborn in lieu of colostrum.


27/9/2000