




## Nutrition Security: Fertilizing Crops for Nutritious Food

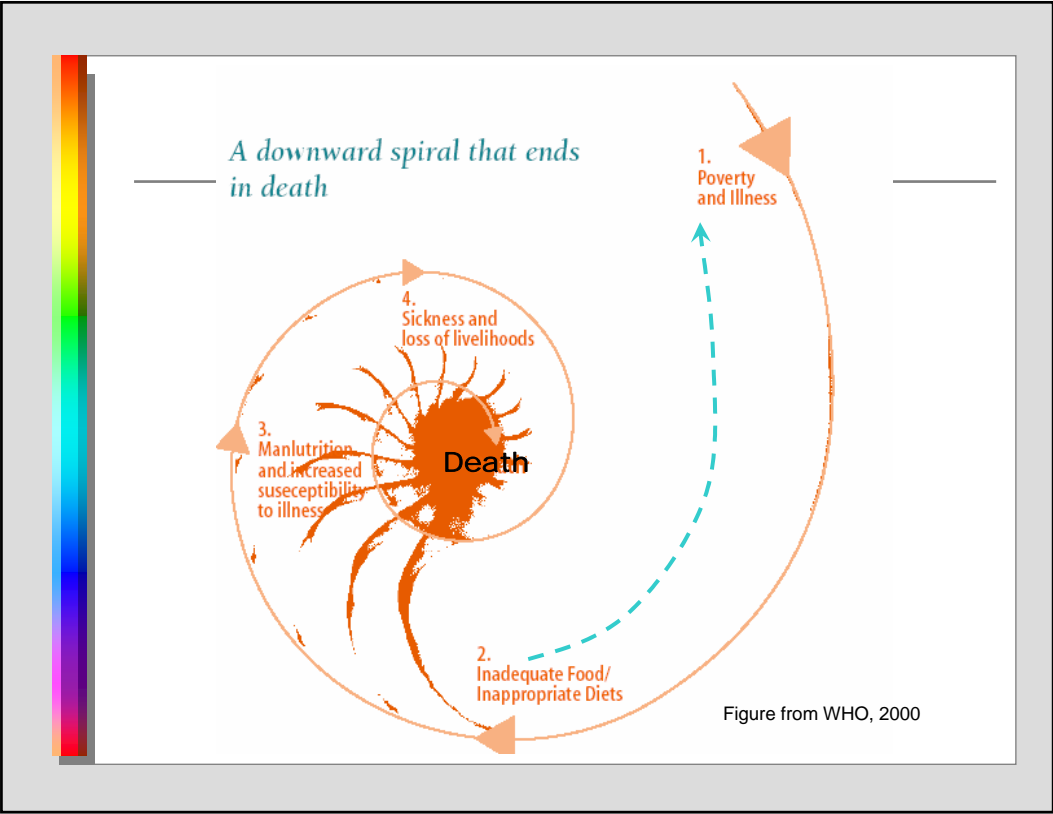
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**Cornell University**



*“Nutrition is a key element in any strategy to reduce the global burden of disease. Hunger, malnutrition, obesity and unsafe food all cause disease, and better nutrition will translate into large improvements in health among all of us, irrespective of our wealth and home country.”*

Dr Gro Harlem Brundtland,  
Director-General, WHO  
at the World Economic Forum 2000

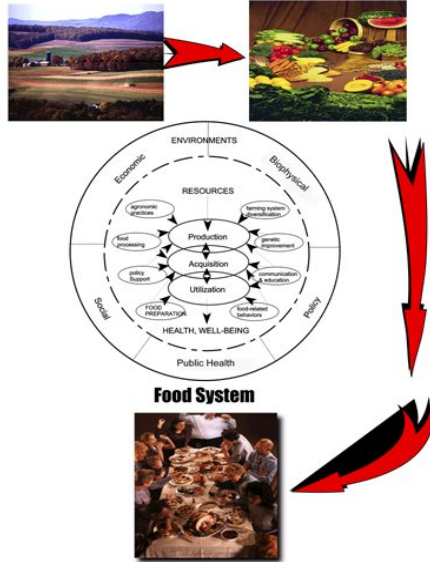
Figure from WHO, 2000



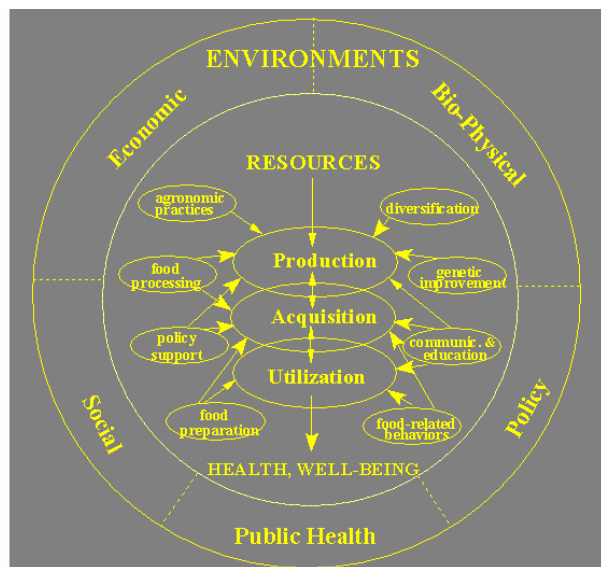
**Agricultural technologies can be directed at improving the “healthiness” of foods to meet human needs, but this require the use of**

→

# Holistic Food System Perspectives to Assure Sustainable Impact



# Holistic Food Systems Model





## Food Systems, Diet and Disease

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- Global food systems are **failing to provide adequate quantities of essential nutrients** and other factors needed for good health, productivity and well being for vast numbers of people in many developing nations.
- *Green revolution* cropping systems have resulted in reduced food-crop diversity and **decreased availability of micronutrients**.
- Nutrition transitions are causing increased rates of **chronic diseases (cancer, heart disease, stroke, diabetes, osteoporosis)** in many developing nations.
- Holistic, **sustainable improvements in the entire food system** are required to solve the massive problem of malnutrition and increasing chronic disease rates in developed and developing countries.
- How can **agriculture** contribute to sustainable solutions?



## Global Food Systems' Problems

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- Agriculture's primary focus is on **production** alone, with little concern for nutritional or health-promoting qualities.
- Nutritionists tend to emphasize unsustainable **medical approaches** to solve malnutrition problems
  - supplements
  - food fortificants
- Simplistic views are the norm – looking for “**silver bullet**” approaches for solutions

## The Known 50 Essential Nutrients for Sustaining Human Life\*

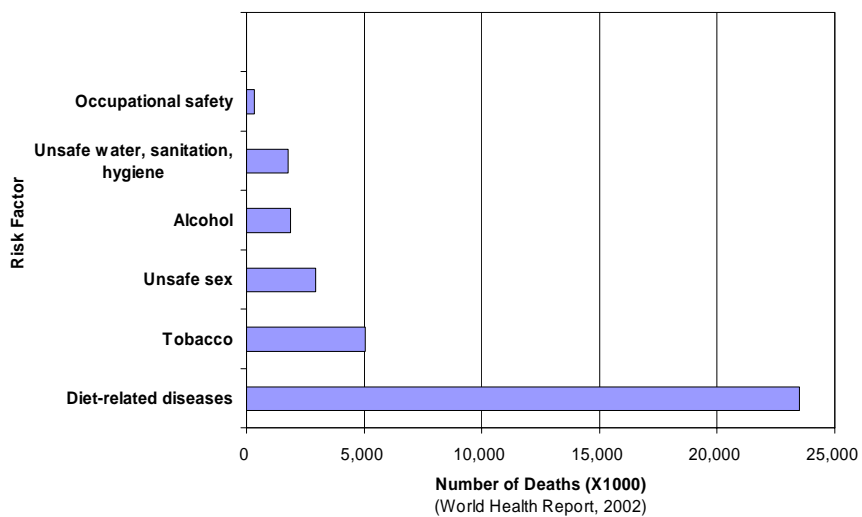
Water & Energy (2)	Protein (amino acids) (9)	Lipids-Fat (fatty acids) (2)	Macro- Minerals (7)	Micro- Elements (17)	Vitamins (13)
Water Carbohydrates	Histidine Isoleucine Leucine Lysine Methionine Phenylalanine Threonine Tryptophan Valine	Linoleic acid Linolenic acid	Na K Ca Mg S P Cl	Fe Zn Cu Mn I F B Se Mo Ni Cr V Si As Li Sn Co (in B <sub>12</sub> )	A D E K C (Ascorbic acid) B <sub>1</sub> (Thiamin) B <sub>2</sub> (Riboflavin) B <sub>3</sub> (Pantothenic acid) Niacin B <sub>6</sub> (Pyridoxal) Folate Biotin B <sub>12</sub> (Cobalamin)

\*Numerous other beneficial substances in foods are also known to contribute to good health.

## WHO Global Strategy on Diet, Physical Activity and Health 57<sup>th</sup> World Health Assembly 2004

- Acknowledged that malnutrition, including undernutrition and nutritional deficiencies is still a major cause of death and disease globally.
- Non-communicable diseases are of crisis proportions in developed countries and is rapidly increasing in developing countries. In 2001, chronic diseases (many diet related) accounted for almost **60% of the 56 million deaths annually and 47% of the global burden of disease.**
- **National food and agricultural policies** should be consistent with the protection and promotion of public health.
- **Agricultural policy** and production have great effects on national diets. Governments can influence agricultural production through many policy measures. As emphasis on health increases and consumption patterns change, **Member States need to take healthy nutrition into account in their agricultural policies.**

### Some WHO Major Risk Factors Causing World Deaths in 2000

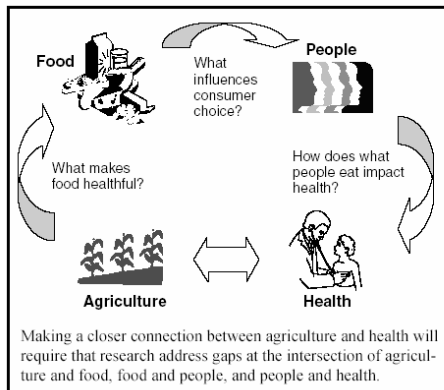


### Table to Farm: A New Agriculture Paradigm

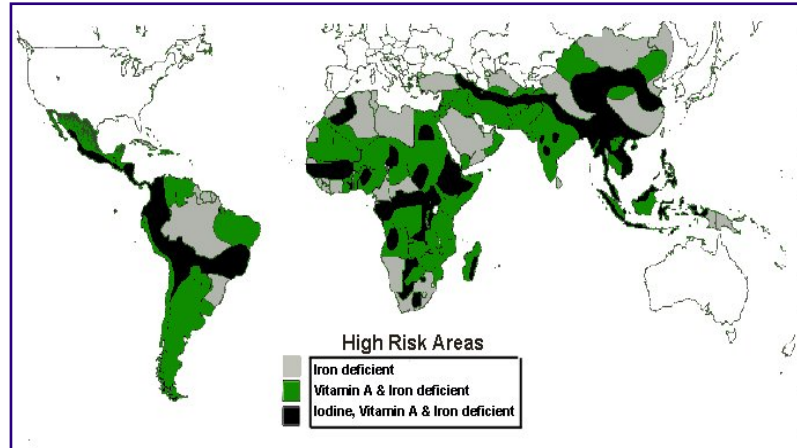
(National Academy of Sciences Workshop - *Exploring a vision: Integrating knowledge for food and health, 2003*)

*“It is time for the United States to shift to a new agricultural paradigm—one based on both what is good for the consumer and profitable for farmers.”* Charles Muscoplat, Dean, College of Agricultural, Food, and Environmental Sciences, Univer. of Minnesota

*“The time is ripe for an integrated approach to nutrition, health, and disease prevention”* Van Hubbard, Director, National Institutes of Health, Div. of Nutr. Res. Coordination



## Global Micronutrient Deficiencies



> 3 billion people afflicted

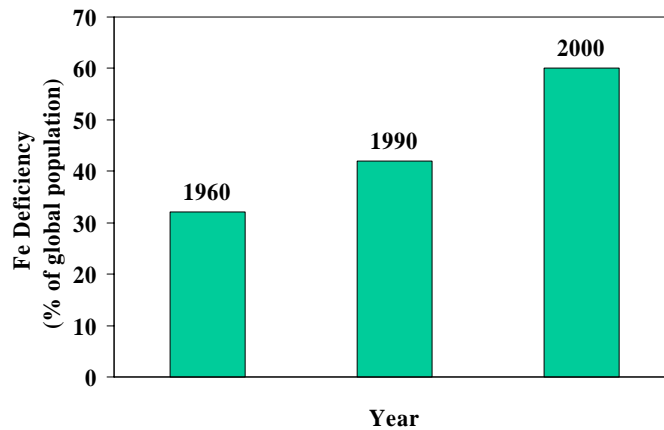
(Map from  
USAID)

## Iron Deficiency Anemia



Picture from World Health Organization

## Change in Prevalence of Iron Deficiency Globally

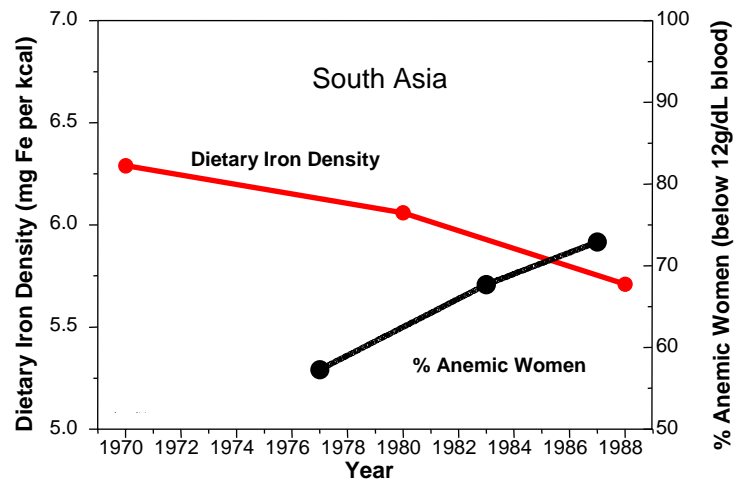


Data from WHO, 2002

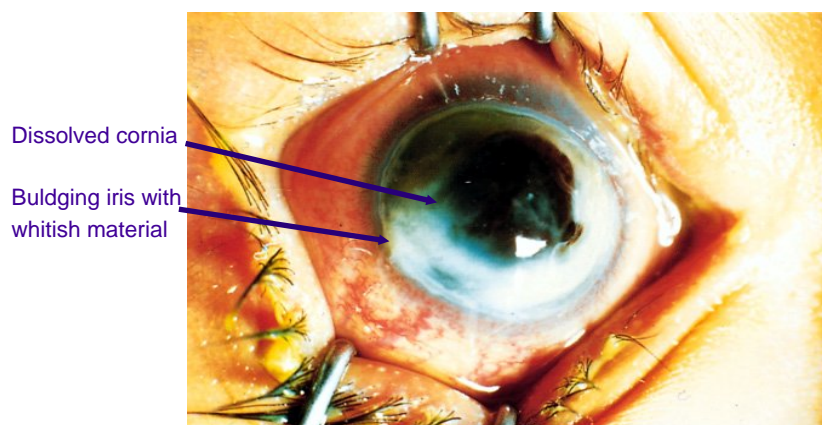
## Some Consequences of Fe Deficiency in Humans

- Irreversible damage to fetal brain development *in utero*
- Impaired cognitive development in infants & children
- Less efficient utilization of food energy sources
- Decreased child survival
- Lower infant birth weights & increased perinatal mortality
- Decreased iron stores in adolescent girls adversely affecting later pregnancies
- Increased maternal mortality rates & obstetrical complications
- Decreased fitness and work capacity
- Increased morbidity and mortality from infectious diseases
- Greater susceptibility to toxicities from heavy metals

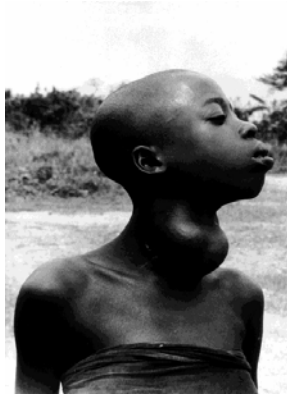
## Dietary Iron Density and % Anemic Women in S. Asia



## Vitamin A Deficiency in a 3-year-old Indonesian Child



## **Iodine Deficiency Goiter & Cretinism**

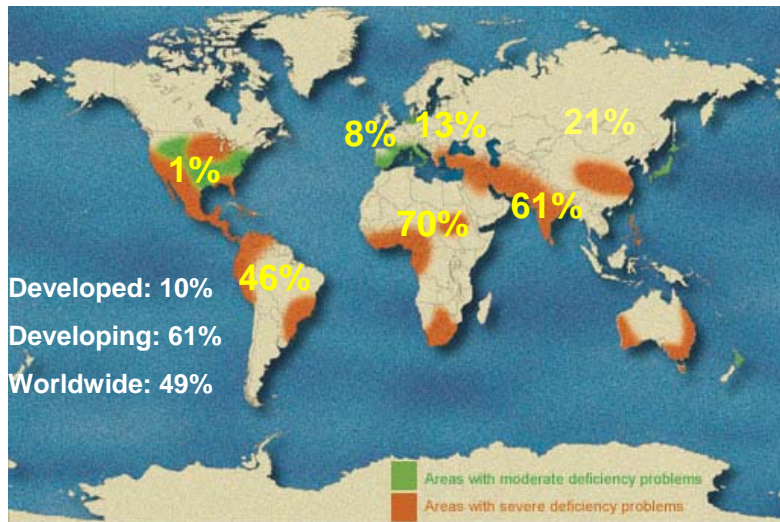


## **Calcium Deficiency Rickets in Bangladeshi Children**



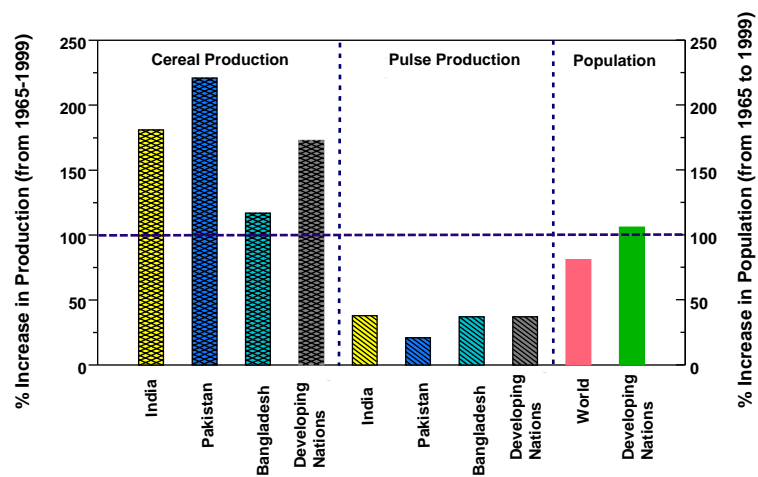
**New disease in Bangladesh; also reported in Nigeria**

## Estimated population at risk of low zinc intake



Brown and Wuehler (2000): Zinc and human health

## % Changes in Cereal & Pulse Production & in Populations Between 1965 & 1999



(FAO data, 1999)

## Micronutrients in Whole Cereal Grains and Legume Seeds (Pulses)

Plant Food	Fe	Zn	Mn	Cu	Mo	Cr	Ni	
( $\mu\text{g g}^{-1}$ dry weight)								
Cereals	Brown rice	20	14	11	2.4	0.78	0.088	-
	Whole soft wheat	39	22	35	4.5	-	0.370	0.31
Legumes	Mung bean	87	41	14	13.0	3.20	0.251	2.04
	Black gram	139	36	19	7.9	0.16	0.530	3.43
	Cowpea	67	45	16	6.3	1.47	0.272	3.44
	Soybean	97	43	26	15.5	-	-	-
	Red kidney bean	64	30	12	6.8	-	-	-

## Effects of Polishing and Milling on Rice Grain Micronutrient Concentrations<sup>a</sup>

Micronutrient	Brown Rice	Polished Rice	% Removed
Iron ( $\text{mg kg}^{-1}$ )	20	5	75
Copper ( $\text{mg kg}^{-1}$ )	3.3	2.9	12
Manganese ( $\text{mg kg}^{-1}$ )	17.6	10.9	62
Zinc ( $\text{mg kg}^{-1}$ )	18	13	30
Biotin ( $\mu\text{g kg}^{-1}$ )	120	50	58
Folic Acid ( $\mu\text{g kg}^{-1}$ )	200	160	20
Niacin ( $\text{mg kg}^{-1}$ )	47	16	66
Pantothenic Acid ( $\text{mg kg}^{-1}$ )	20	10	50
Riboflavin ( $\text{mg kg}^{-1}$ )	0.5	0.3	40
Thiamin ( $\text{mg kg}^{-1}$ )	3.4	0.7	80
Vitamin B <sub>6</sub> ( $\text{mg kg}^{-1}$ )	6.2	0.4	94
Vitamin E ( $\text{IU kg}^{-1}$ ) <sup>b</sup>	20	10	50

<sup>a</sup>Dry weight basis.

<sup>b</sup>IU = International Unit.

(Data from Lockhart & Nesheim, 1978)



## Agricultural Approaches to "Healthier" Plant Foods

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- Field Site Selection
- Agronomic Practices
  - macronutrient fertilizers
    - nitrogen, phosphorus, potassium, sulfur, calcium, magnesium
    - effects protein, fats, vitamins, antinutrients, etc.
  - micronutrient & trace element fertilizers
    - Zn, Se, I, Co, Ni, Mo, Li, Cl - effective in increasing amount in plant seeds and grains
    - Fe, Cu, Mn, B, Cr, V, Si - not very effective in increasing seed or grain levels
- Cropping systems
  - legume-cereal rotations -effects micronutrient content
  - use micronutrient-dense varieties of food crops
  - increase production of vegetables, fruits, & legumes
- Utilize indigenous plant foods and diversify food systems
- Genetically modify food crops to improve nutrient output of farming systems



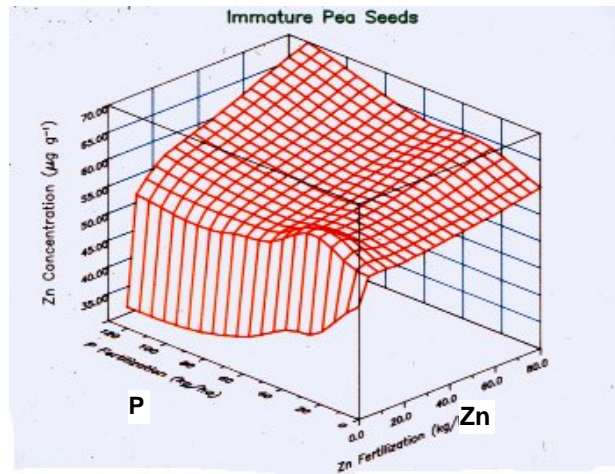
## Effects of Zn Fertilization on Yield & Zn Concen. of Wheat Grain

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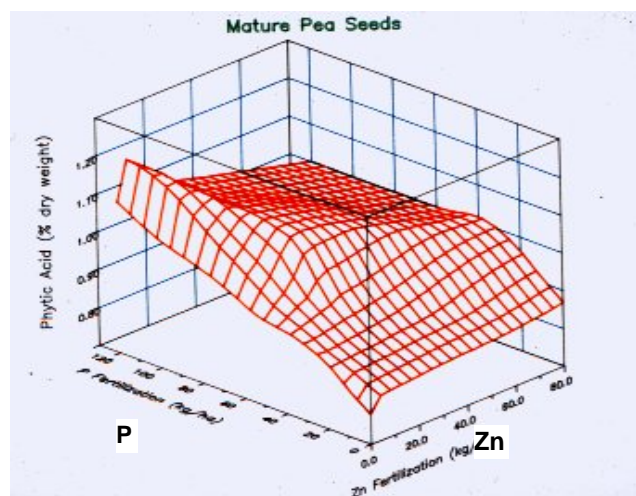
Zn Treatment (mg/kg soil)	Grain yield (g/plant)	Zn concen. (mg/kg)
0	1.00	9.1
0.05	2.20	9.9
0.2	2.24	14
0.8	2.51	83
3.2	1.70	145

Data from Rengel et al. (1999)

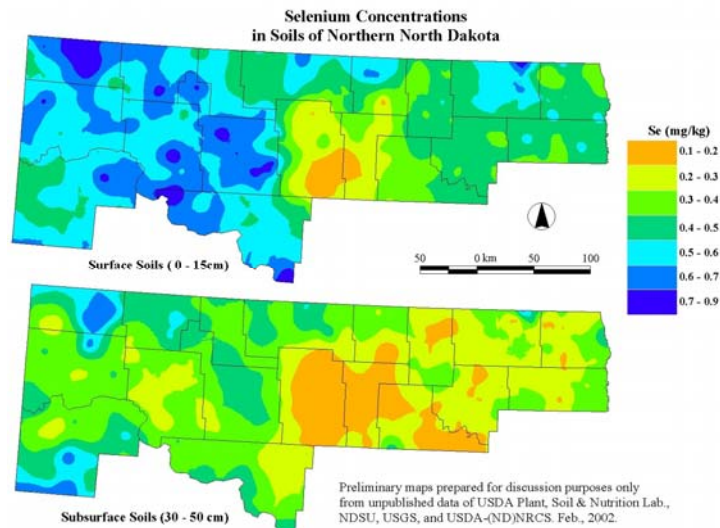
## P & Zn Fertilizer effects on Zn levels in pea seeds



## Zn and P fertilizer Effects on Phytic Acid in Pea Seeds



## Total Soil-Se in North Dakota Sites



## Effect of Se Fertilization (6 or 16 mg kg<sup>-1</sup>) in Finland on Blood Serum Se Levels in 21year-old Finish Students

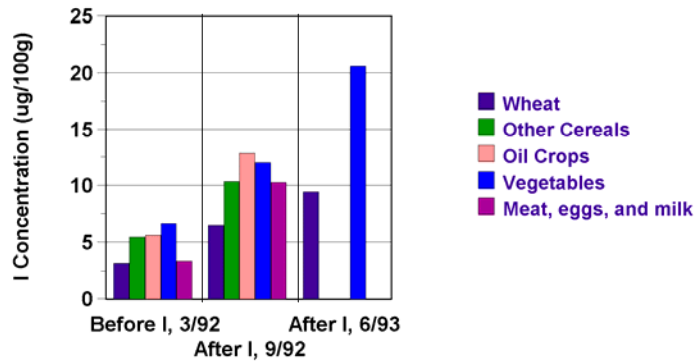
<u>Year</u>	<u>Serum-Se (μmole L<sup>-1</sup>)</u>
• 1985 (baseline)	1.05
• 1989	1.60
• 1991	1.58

< 1 μmole L<sup>-1</sup> serum-Se related to increased cancer risk.

(Data from Makela et al., Biol. Trace Element Res. 36: 151-157, 1993)

## Food Systems Approach to Iodine Deficiency Disorders

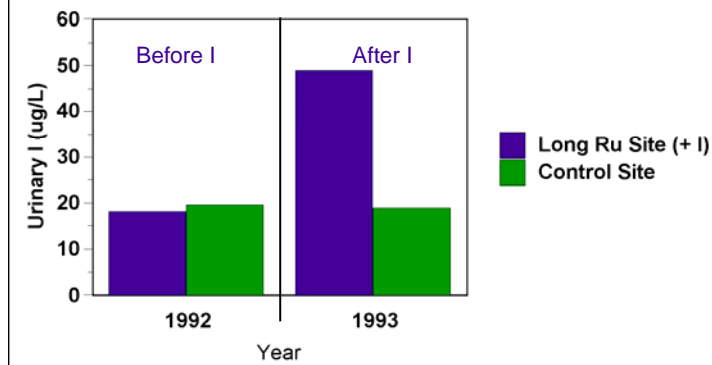
### Effects of Iodination of Irrigation Water Long Ru, China



Cao, et al., 1994

## Food Systems Approach to IDD

### Effects of Iodate Irrigation on Urinary I Children 2-6 years old



Cao, et al., 1994

## Effects of N & K Fertilizers on Vitamin C

(mg/100g fr. wt.)

Vegetable	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>
<i>Swiss chard</i>	67.8	56.1	47.6
<i>Kale, collards</i>	113.0	112.0	66.0
<i>Brussels-sprouts</i>	112.0	101.0	93.0
Vegetable	K <sub>1</sub>	K <sub>2</sub>	K <sub>3</sub>
<i>Swiss chard</i>	49.9	56.1	59.3
<i>Kale, collards</i>	98.0	112.0	118.0
<i>Brussels-sprouts</i>	88.0	101.0	100.0

(data from Salunkhe and Deshpande, 1991)

## Effects of N and Harvest Date on $\beta$ -Carotene Content of Carrots

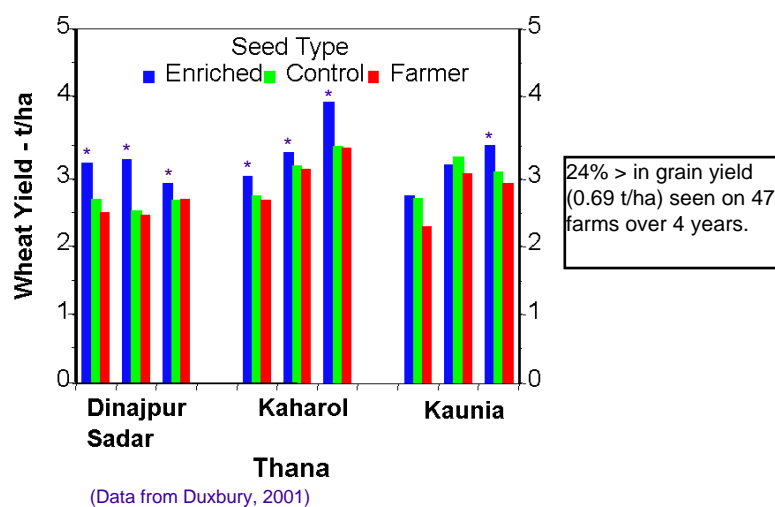
Treatment	Carotene (mg/100g)	Carotene (mg/100g)	Carotene (mg/100g)
(kg N/pot)	1st harvest	2nd harvest	3rd harvest
0.3	113	125	136
0.6	118	128	138
1.2	126	138	147
2.4	126	138	146

from Habben (1972)

## Agronomic Benefits of Micronutrient Element-Enriched Seeds (e.g. Zn)

- Better seed viability
- Greater seedling vigor
- Denser stands (less soil erosion)
- Lower seeding rates (lower cost to farmers)
- Larger root absorptive surface (better water & nutrient use efficiency)
- Better resistance to disease
- Better plant survival
- Increased plant & seed yield

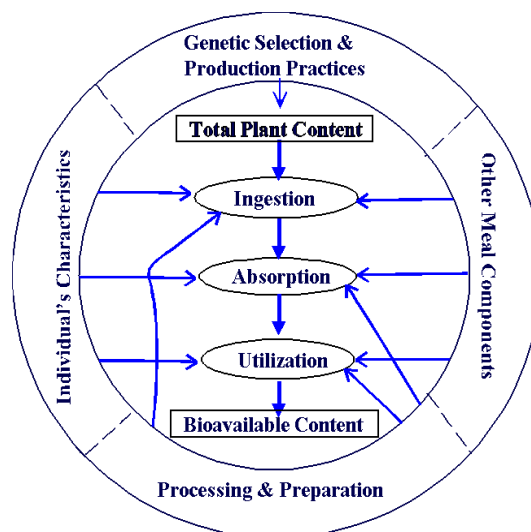
## Effects of Micronutrient-Enriched Seed on Wheat (Kanchan) Grain Yields from 9 Farms in Bangladesh



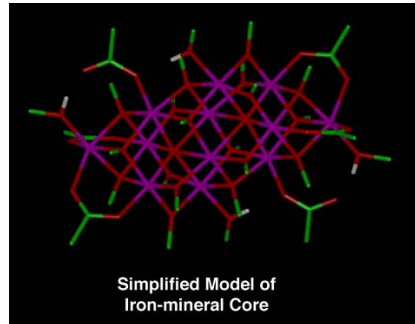
## The Importance of Bioavailability

- Definition – the amount of a nutrient in a food that can be absorbed from a typical diet and utilized in the body
- **Bioavailable amount** of a micronutrient in a meal, **not the total amount**, is the critical factor for human health
- Most staple plant foods (cereal grains and legume seeds) fed alone contain very low levels of bioavailable Fe and Zn (e.g., about 5%) because of the antinutrients they contain (phytate, polyphenols, etc.)
- Increasing the bioavailability of micronutrients from 5% to 30% would have the same effect as increasing their total amounts in staples by 6 fold

## Complexities of Bioavailability



## Structure of Ferritin



## Bioavailable Fe in Intrinsically $^{55}\text{Fe}$ -labeled Tokyo Variety of Soybeans<sup>1</sup> Fed to Women

Feeding day	Soy soup	Soy muffin
	(% absorbed) <sup>2</sup>	(% absorbed) <sup>2</sup>
Day 14	25.9	28.7
Day 28	24.5	27.0

<sup>1</sup>Soybeans (Tokyo variety) contained 30-50% of their total Fe as ferritin and 2.1% phytic acid.

<sup>2</sup>Mean of 18 subjects with depleted Fe stores

Data from Murray-Kolb et al., 2002



## **Agriculture's Agenda For Better Health**

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- **Make human health and well being an explicit goal of agricultural systems in addition to productivity & environmental goals**
- **Re-diversify cropping systems & design for maximum nutrient output**
- **Make more use of indigenous micronutrient-dense edible plant species, small livestock, & fish**
- **Use agricultural practices (including fertilizers) that increase the bioavailable micronutrient output of farming systems**
- **Breed for and select for bioavailable micronutrient-dense staple food crops with micronutrient efficiencies**
- **Genetically modify plants to increase nutritional & health promoting factors**
- **Redefine sustainable agriculture to include adequate nutrient output for healthy & productive lives**