Potential impact of crop diversification and biotechnological inventions on the use of micronutrients

Hillel Magen & Patricia Imas,
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- Prophecy was given to fools = no more prophets available, and only fools accept the job……
- He, who adds, lessens.

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Outline

- The effect of crop diversification on micronutrient use
  - Legumes,
  - Vegetables and fruits
  - Prospects of diversification
- Impact of biotechnological Inventions on micronutrients use
  - Current status of GM crops,
  - Future traits,
  - Direct and indirect effects,
- Conclusions

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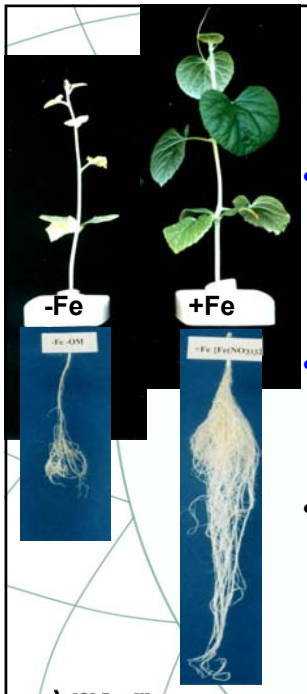

Most deficient micronutrients

- Fe deficiency – in ~30% of cultivated soils worldwide (calcareous, high pH),
- Zn deficiency – in ~50% of cereal production soils,
- More than 3 billion people suffer from Fe and Zn deficiency.

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Source: Chen & Barak, 1982; Lucca et al., 2001; Graham et al., 2001; Cakmak, 2002; Welch, 2002.

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How can crop diversification and biotechnological inventions affect the use of Fe and Zn, while they lack due to:

- Soil deficiency,
- Low availability in soil,
- Low availability in plant tissue?

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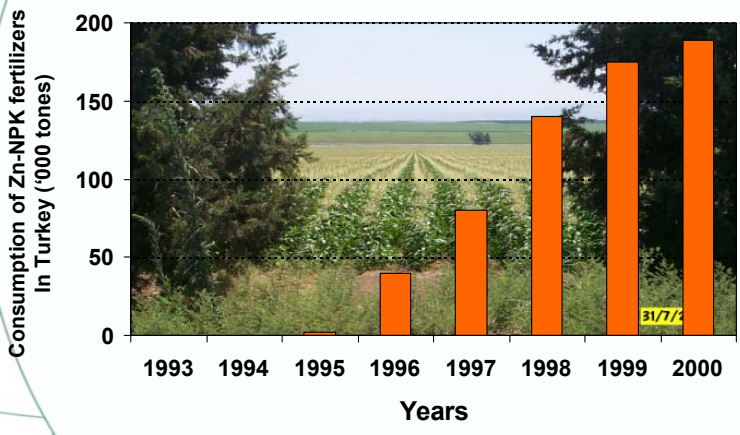
Figure 1

Consumption of Zn-containing NP and NPK fertilizers in Turkey – in response to Zn deficiency in soil



Source: Cakmak, 2002

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Biomass levels and micronutrient uptake by rice and wheat, under different NPK fertilization rates.

Fertilization rate (kg/ha $N;P_2O_5;K_2O$)	Biomass (t/ha)		Rice (kg/ha)				Wheat (kg/ha)			
	Rice	Wheat	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe
0:0:0	6.5	4.1	0.12	0.09	0.35	1.68	0.07	0.03	0.11	0.70
60:30:30	8.8	7.5	0.17	0.13	0.57	2.51	0.12	0.05	0.21	1.30
120:60:60	12.9	10.2	0.25	0.19	0.80	3.43	0.17	0.08	0.28	1.83
180:90:90	14.5	12.4	0.30	0.22	0.97	4.06	0.20	0.09	0.33	2.33

Source: Gupta and Mehla, 1993.

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Diversification

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Diversification through integration of legumes: Micronutrient content and yield effect

- Legumes in rotation with cereals increase Zn levels in cereals,
- Legumes have higher content of micro nutrients and are not polished (as compared to cereals),
- Maize yields increased 2 fold after sole cropped legumes.

Source: Welch, 2003; Brougton, 2003; Cakmak, 2002.

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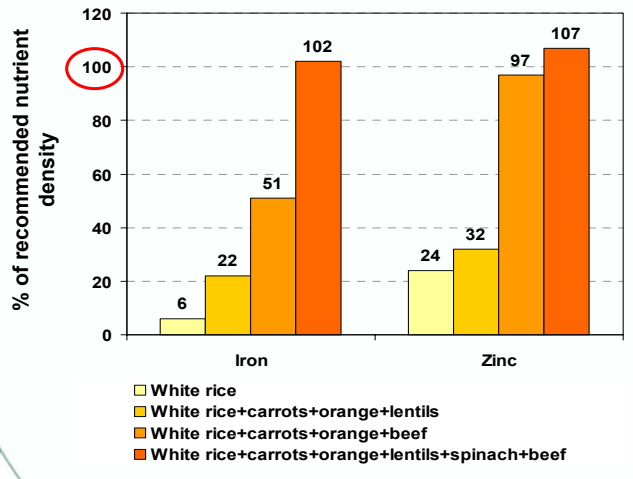
Figure 2

Percentage of recommended nutrient density for a diet of white rice and the addition of a variety of foods



Adapted from Human Vitamin and Mineral Requirements. World Health Organization - FAO. (2002)

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Vegetables are considered the most affordable and sustainable sources of micronutrients
Asian Vegetables Research and Development Center
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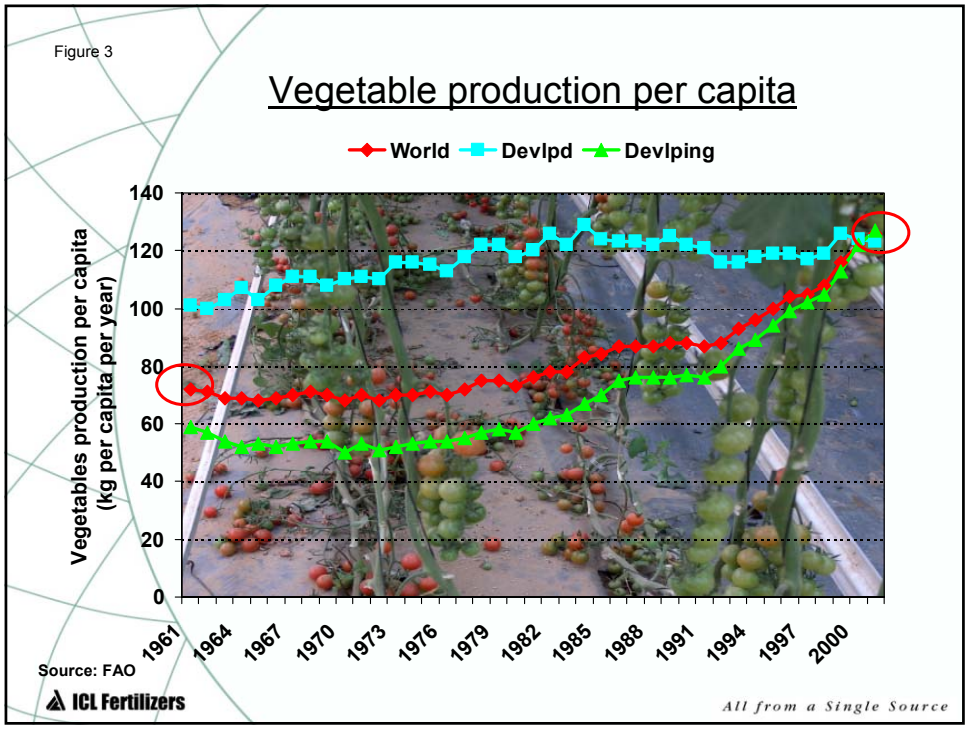
Figure 3
Vegetable production per capita
World
Devlpd
Devlping
Vegetables production per capita (kg per capita per year)
140
120
100
80
60
40
20
0
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
Source: FAO
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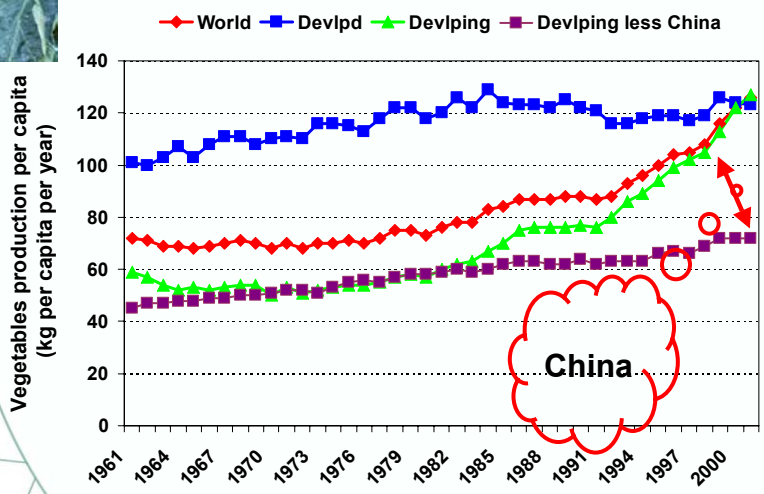
Figure 4

Vegetable production per capita



Source: FAO

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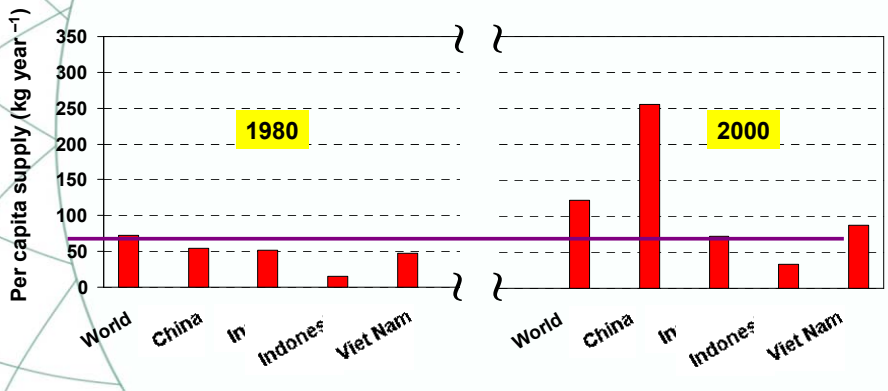
Figure 5

Vegetable production per capita in selected countries



Source: FAO

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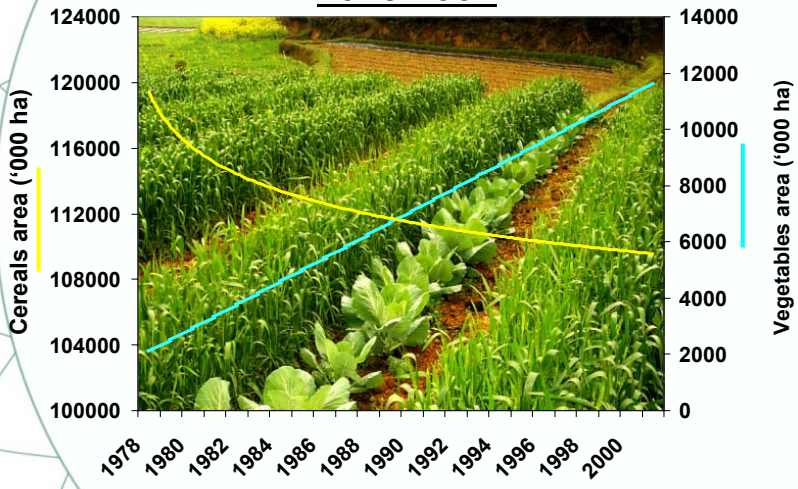
Figure 6

Area under cereals and vegetables in China, 1978-1997



Source: China Statistical yearbook, 1998.

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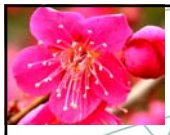

Impact of crop diversification:

Agronomical possible, yet -

	Cereals	Legumes	Veg & fruit
Micronutrient content / availability	low ←	higher	higher
Higher yields	↔		

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Impact of crop diversification:

Possible, but why to, and who will pay?

	Cereals	Legumes	Veg & fruit
Micronutrient content / availability	low ←	higher	higher
Higher yields	↔		
Economics	good	medium	very good
Drive for diversification		medium	high

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Possible future – GM veg?

Impact of Biotechnological Inventions on Micronutrients Use

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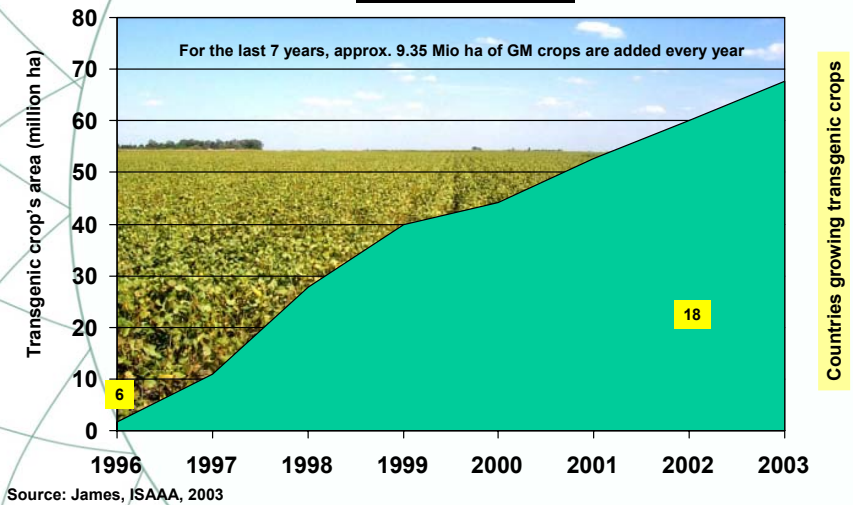
Figure 7

Global area of genetically modified crops, 1996 to 2003



Source: James, ISAAA, 2003

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Area under transgenic crops in various countries.

Country	Area (Mio ha)	Major crops
USA	42.8	Soybean, maize, cotton, canola
Argentina	13.9	Soybean, Bt maize, cotton
Canada	4.4	Canola, maize, soybean
Brazil	3.0	Soybean
China	2.8	Bt cotton
S. Africa	0.4	Maize, soybean, cotton
Australia	0.1	Cotton
India	0.1	Cotton
Romania	<0.1	Soybean
Uruguay	<0.1	Soybean, maize
Spain, Mexico, Philippines, Colombia, Bulgaria, Honduras, Germany and Indonesia.	<0.05 each	Mostly maize
World	*67.7*	

Source: James, ISAAA, 2003

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Global area of transgenic crops in 2003.

Crop	Area (Mio ha)	Trait	% Of total GM area
Soybean	**41.4**	**Herbicide tolerance**	**61**
Maize	**15.5**	**9.1 Mio for Bt**	**21**
Cotton	**7.2**		**11**
Canola	**3.6**		**5**

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Future development of rice traits

Input traits

Trait		2003-2005	2006-2008	2009-2012
Herbicide resistance		***		
Disease resistance		* To ***	**	**
Virus resistance		*	**	***
Insect resistance		***		
Nutrition	Vitamin A	*	***	
	Iron bioavailability	*	** To ***	***
	High-quality protein		**	***
A-biotic stress	Salt and drought tolerance		**	***
Yield			* To **	***

Output traits

"*" = 30-50% likelihood
"" = 50-80% likelihood**
"*" = >80% likelihood**

Adapted from Brooks and Barfoot, 2003

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Traits with Improved Fe and Zn Uptake and Bioavailability

Bioavailability:
- **Ferritin,**
- **Phytic acid**

Uptake:
- **Iron acquisition,**
- **Higher secretion of reductase**

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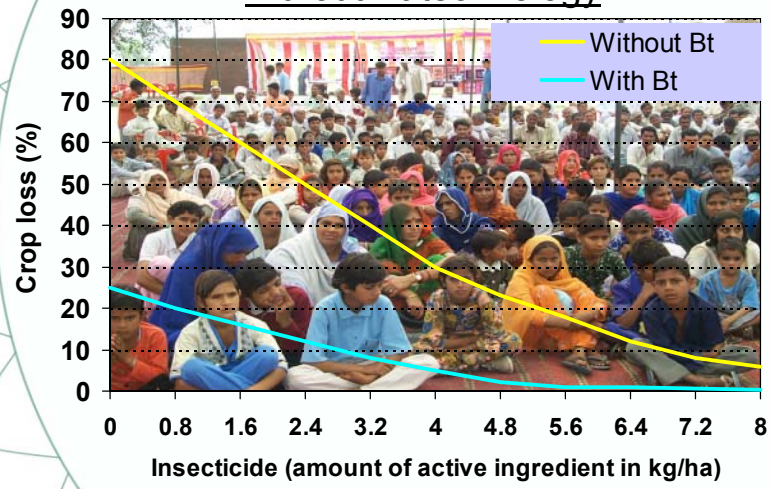
Figure 8

Insecticide use and crop losses with and without Bt technology



Adapted from Qaim and Zilberman, 2003

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Expected yield effects of pest-resistant GM crops in different regions

Region	Pest pressure	Availability of chemical alternatives	Adoption of chemical alternative	Yield effect of GM crops
Developed countries	Low – medium	High	High	Low
L. America (commercial)	Medium	Medium	High	Low - medium
China	Medium	Medium	High	Low - medium
L. America (non-commercial)	Medium	Low - medium	Low	Medium – high
S. SE. Asia	High	Low - medium	Low – medium	High
Africa	High	Low	Low	High

Source: Qaim and Zilberman, 2003.

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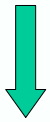
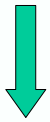
How can biotechnology affect micronutrient use?





Indirect:
Higher yields,
Higher income,
Higher removal.

Direct:
Higher assimilation
of micronutrients,
Higher content
of micronutrients.

Source: de Oliveira and Montagu, 2003;

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Some more points for consideration:

- Consumer awareness,

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GMO crops also enhance biodiversity and environmental sustainability through reduction in pesticide use. Pesticide use has increased 53 times between 1950 and 2000 leading to serious problems for human health, food quality and destruction of useful flora and fauna.

G. Kush: Biotechnology, food security, food safety and environmental sustainability

Some more points for consideration:

- Consumer awareness,
- Economic considerations,

Golden Rice

Golden Rice' is a GM rice genetically engineered to produce beta-carotene, a substance that the body can convert to Vitamin A. This will help to fight vitamin A deficiency (VAD), a condition which afflicts millions of people in developing countries, especially children and pregnant women.

Source: Miflin, 2000

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Some more points for consideration:

- Consumer awareness,
- Economic considerations,
- Alternatives for supplying Fe and Zn

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Conclusions

- Population growth and need for better diets,
- Strong crop diversification through market driven crops (vegetables and fruits),
- Improved agronomic results due to GM crops drive micronutrient demand,
- Who will invest in 'output' GM crops and will they require more – or less micronutrients?
- Still need for prophecy..

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