Enhancing Crop Productivity through Zinc Application

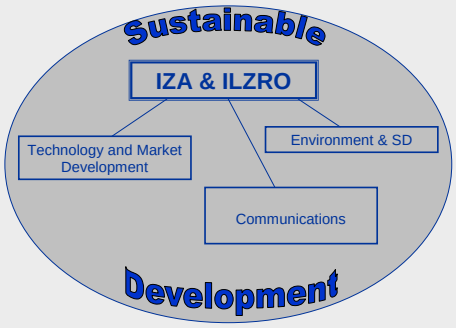
Fertilizer Association of India
Annual Seminar
New Delhi, 5-7 December, 2007

Johan Van Wesemael
Manager Technology & Market Development
International Zinc Association

International Zinc Association

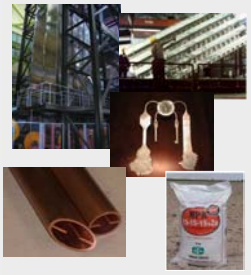
- Founded in 1990
- 40 Members & 35 Affiliates
  - 80% of WW zinc production
  - 50% of world production

International Zinc Association Program Areas

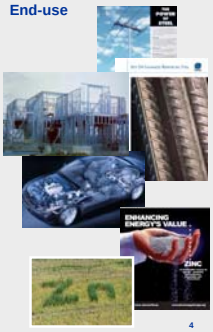


Activities Technology & Market Development

First-use



End-use

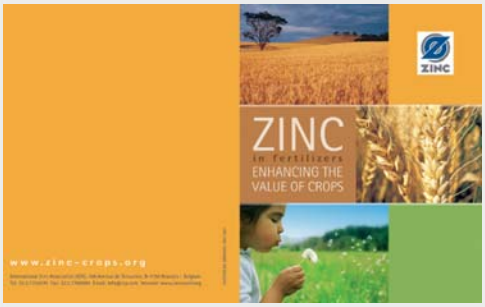


Zinc And Health

- Zinc and Health Brochure
- Support the International Zinc Nutrition Consultative Group (IZiNCG) core costs
- Zinc supplementation program in Peru
- Health conferences: Peru, Washington

Crop Nutrition Programs

- Market Development seminar in Brazil, Dec. 2006
- International scientific conference, "Zinc Crops – May 2007" in Turkey
- Close collaboration with International Fertilizer Association



Overview

- Positioning of zinc & market data
- Zinc deficiency
- Zinc as a micronutrient
- Zinc and health
- Conclusion

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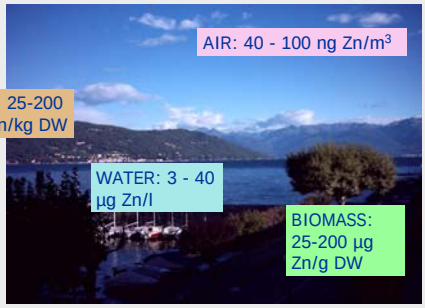
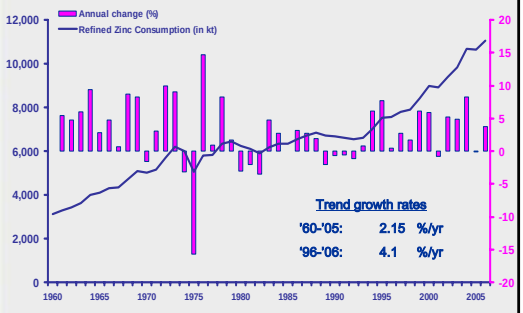
Zinc is a natural element

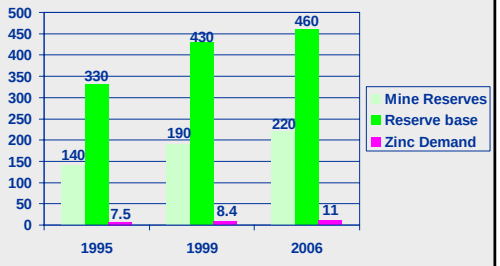


World Zinc Demand



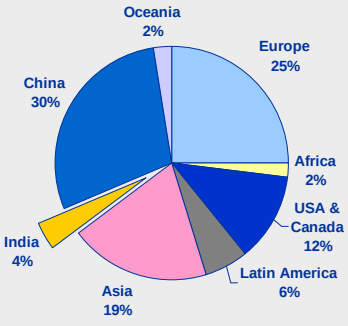
Source: ILZSG (refined zinc consumption-February 2007 publication), IZA

Zinc Reserves (million tonnes)



Source: U.S. Geological Survey, 2007

Zinc Demand by Region



Source: ILZSG(Refined Zinc Consumption 2007/Bull. 9) - IZA

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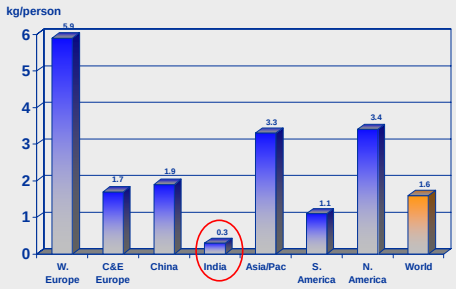
Zinc Consumption per person 2003*



Source: ILZSG, Worldbank, IZA

* mid year/3 year average : 2002-2003-2004

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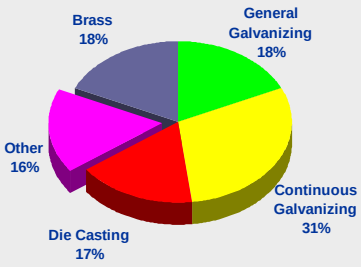
Zinc Demand by First Use Market



Source: ILZSG (reported zinc consumption-excl. China) , IZA

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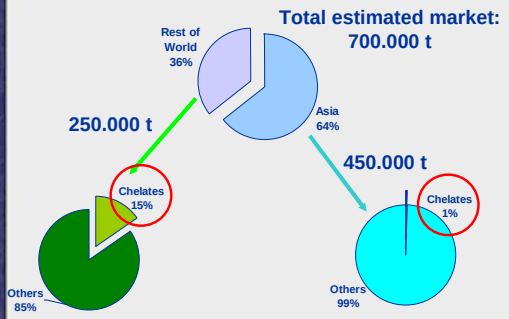
Market Micronutrients 2006



Source: Discussions (Akzo Nobel, SQM, IFA); IZA

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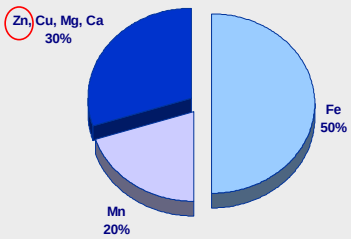
Market Chelated Micronutrients 2006



Total market: 43.000 t

Source: Discussions (Akzo Nobel, SQM, IFA); IZA

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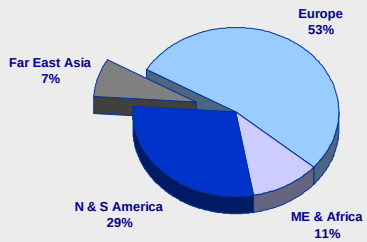
Chelated Micronutrients Market 2006

Total market: 43.000 t



Source: Discussions (Akzo Nobel, SQM, IFA); IZA

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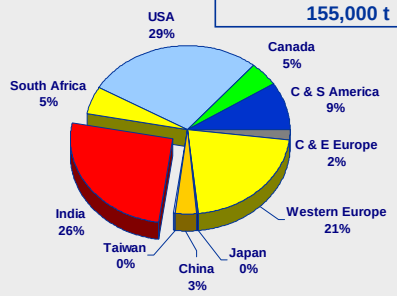
Zinc Sulfate Demand 2006

Estimated Total Demand: 155,000 t



Source: Discussions (Akzo Nobel, SQM, IFA); SRI Consulting; IZA

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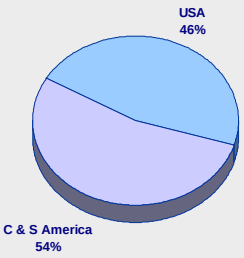
Zinc Chloride Demand 2006

Total Estimated Demand: 20,500 t



Source: Discussions (Akzo Nobel, SQM, IFA); SRI Consulting; IZA

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- **Zinc deficiency**
- Zinc as a micronutrient
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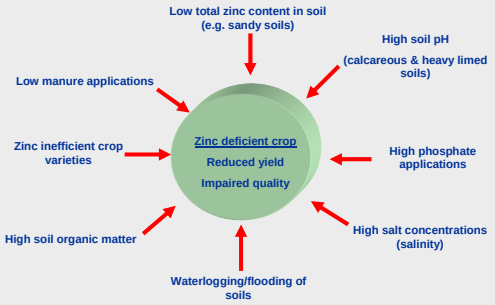
Causes of Zinc Deficiency



Source: Alloway – Zinc in soils and crop nutrition, Lindsay-Zinc in soils and plant nutrition

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Zinc Deficiency

- Decrease in SOD Activity
- Increase in NADPH Oxidase
- Inhibition of Protein Synthesis
- Decrease in H_2O_2 Scavenging
- Increase in Light-Induced $O_2^{\cdot-}$ - Generation

→ **High Levels of Free Radicals** →

- Leaf Chlorosis/Necrosis
- Inhibition of Growth
- Membrane Damage

Source: Cakmak, 2000; New Phytologist, 146: 185-205

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Recognizing Zinc Deficiency

- **Chlorosis**
- **Necrotic Spots on leaves**
- **Bronzing of Leaves**
- **Rosetting of Leaves**
- **Stunting of Plants**
- **Dwarf leaves**
- **Malformed leaves**

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Comparing deficiencies

Zinc deficiency

Symptoms on NEW and OLD leaves

Copper, Iron, Manganese & Sulphur deficiency

Symptoms only on NEW leaves

N,P, K, Magnesium & molybdenum deficiency

Symptoms only on OLD leaves

Source: Alloway, 2003

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Zinc deficiency in rice - Examples

Rice plants in paddy field

Young rice plants with chlorosis

Severe Zn deficiency

Zn treated plot

Pictures: Potash & Phosphate Institute; Int'l Rice Research Insititute

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Zinc Deficiency in Maize & Wheat

Maize showing white bud and interveinal chlorosis

Picture: Potash & Phosphate Institute, Courtesy of Prof. I. Cakmak

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Zinc Deficiency

- 50% world's cereal production potentially zinc deficient:
  - 25% acute
  - 25% hidden
- Most sensitive are maize, beans, cotton and citrus fruits
- Less sensitive wheat and rice but suffering in many parts of the world
- Turkey, Australia, China

Zinc deficiency is most widespread

Source: B. Alloway – New AG International March 2006, Zhang 2006, Cakmak 2006

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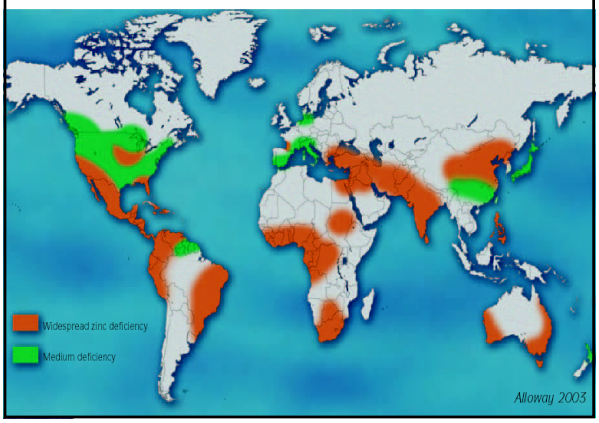
World zinc deficiency in soil: major areas of reported problems



Zinc Deficiency in Southern Africa

Source: Dr.O. Ohiokpehia, TSBF of CIAT, Istanbul 2007

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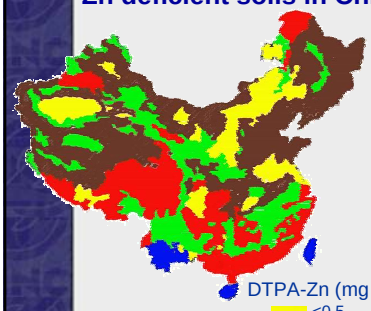
Zn deficient soils in China



- ✓ -Zn Area: 486 million hectares
- ✓ Percentage of agricultural field: 50%
- ✓ Main crops: Maize , rice , fruit trees…

DTPA-Zn (mg kg^{-1})

<0.5	very low	2.0-5.0	high
0.5-1.0	low	>5.0	very high
1.0-2.0	medium		

Source: F. Zhang, Istanbul 2007, Zinc Crops Conference

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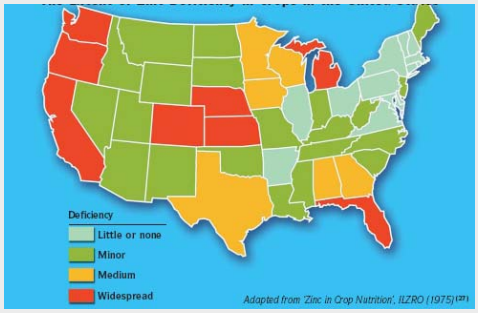
Zinc deficiency in the USA



Source: Alloway, Zinc in soils and crop nutrition, 2003

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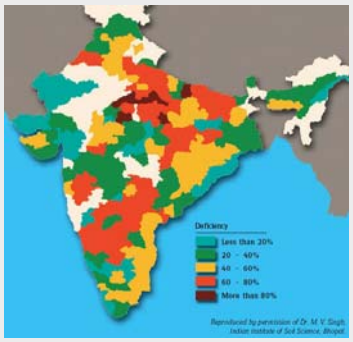
Areas of zinc deficiency in India



Source: Alloway 2003; Indian Institute of Soil Science

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Zinc deficiency

- Widely on the Indo-Gangetic Plain for rice & wheat
- Yield Gap
- Alluvial soils & soils of the wheat belt
- High yielding tea growing areas

Sources: Savithri et all., Nutrient Cycling in Agrosystems; Mandal et all., Soils Science Society of America Journal

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Susceptibility of some important food crops

	Boron	Copper	Iron	Manganese	Molybdenum	Zinc
Wheat		↑↑	↑	↑↑	↑	↑
Rice			↑			↑↑
Maize	↑			↑↑		↑↑
Potato	↑			↑↑		↑
Barley		↑↑	↑	↑		
Soya bean			↑↑	↑↑	↑↑	↑↑
Oats		↑↑		↑↑	↑	
Sorghum		↑	↑↑	↑↑		↑↑
Sugar beet	↑↑	↑		↑↑	↑	
Groundnuts	↑↑		↑↑		↑	↑
Field beans			↑↑	↑↑	↑	↑↑
Chik peas					↑	
Pigeon peas					↑	
Bananas	↑					
Coconuts	↑					

↑↑ Highly susceptible ↑ Moderately susceptible Source: Akzo Nobel, IFA, 2004

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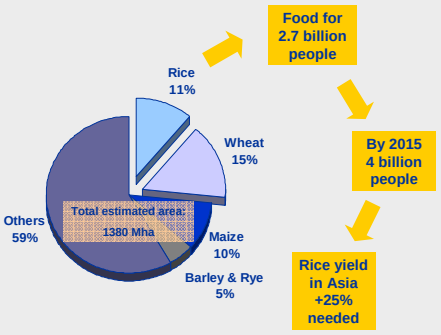
Total area arable land



Source: Alloway 2003, Maclean et al. Rice Almanac 3rd edition

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Zinc as a micronutrient

Four types:

- **Inorganic sources:**
  - **ZnO, $ZnCO_3$, $ZnSO_4$, $ZnCl_2$**
- **Synthetic chelates**
  - **Zn-EDTA**
- **Natural organic complexes**
- **Inorganic complex**
  - **Ammoniated $ZnSO_4$, Ammoniated $ZnCl_2$**

Source: B. Alloway, Zinc in soils and Crop nutrition, 2003; Mortveldt et al. Zinc in Soils and plants

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Commonly used Zn Fertilizer materials

Compound	Formula	Zinc Content (%)
Inorganic Compounds		
Zinc Sulphate Monohydrate	$ZnSO_4.H_20$	36-37
Zinc Sulphate Heptahydrate	$ZnSO_4.7H20$	22-23
Zinc Oxysulphate	$xZNSO_4.xZnO$	20-50
Basic Zinc Sulphate	$ZnSO_4.Zn(OH)_2$	55
Zinc Oxide	ZnO	80
Zinc Carbonate	$ZnCO_3$	50-56
Zinc Chloride	$ZnCl_2$	50
Zinc Nitrate	$Zn(NO_3)_2.H_2O$	23
Sulphurous Zinc	ZnS	67
Zinc Frits	Fritted Glass	10-30
Ammoniated Zinc Sulphate Solution	$Zn(NH_3)_2.3H_2O$	10
Organic Compounds		
Disodium Zinc EDTA	$Na_2ZnEDTA$	8-14
Sodium Zinc HEDTA	NaZnHEDTA	6-10
Sodium Zinc EDTA	NaZnEDTA	9-13
Zinc polyflavonoids		5-10
Zinc Lignosulfonates		5-8

Source: Alloway 2003; Mortveldt & Gilkes, Martens & Westerman, Srivasta & Gupta

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Zinc as a micronutrient

- **Zinc enriched DAP (di-ammonium phosphate)**
- **Nitro-phosphorous fertilizers**
- **Maize preceeded by rice (pre-flooding soils) improves utilization of zinc fertilizers**

Sources: Savithri et all., Nutrient Cycling in Agrosystems; Mandal et all., Soils Science Society of America Journal

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Crop response to treatments

	Zinc	Copper	Boron	Manganese	Iron
Alfaalfa	L	H	H	L	-
Barley	M	M	L	M	M
Canola	M	H	H	M	-
Clover	L	M	M	M	-
Corn (Maize)	H	M	L	M	M
Grass	L	L	L	M	H
Oats	L	H	L	H	M
Pea	L	L	L	H	-
Potato	M	L	L	H	-
Rice	H	H	L	L	-
Rye	L	L	L	L	-
Sorghum	H	M	L	H	H
Sugar beet	M	M	M	H	H
Wheat	L	H	L	H	L

L=low; M=Medium; H=high

Source: Alloway 2003; Mainly based on Martens & Westerman

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Maize, Paraguay, 1996

Picture: I. Cakmak; Modified slide from Dr. Kevin Moran: "*Farming for Health*", Oslo, Oct.-2005

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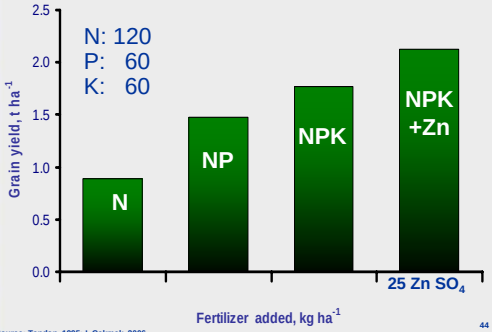
Crop response

Before treatment

15 days after micronutrient application

Source: Stoller

Wheat Grain Yield Based on Long-term Multi Location Experiments in **India**



Source: Tandon, 1995; I. Cakmak, 2006

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Fighting zinc deficiency in soils

- Difficult for a general rule
- Zinc requirement depends on:
  - Soil characterisitics
  - Source of zinc
  - Severity of deficiency
  - Crop variety

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Typical examples

- Wetland Rice:
  - Broadcasting: 10 kg $ZnSO_4$ per hectare
  - Root dipping: 2% ZnO solution
- Wheat:
  - Broadcasting: 5 to 20 kg per hectare
  - Banding: 3 to 5 kg
  - Foliar: 0.015 to 0.25 kg per hectare
    - Mostly used to correct acute deficiency

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Zinc deficiency in humans

Developing Countries

Risk Factor	DALY (in %) *
Underweight	14.9
Unsafe sex	10.2
Unsafe water	5.5
Indoor smoke	3.7
Zinc deficiency	**3.2**
Iron deficiency	3.1
Vitamin A deficiency	3.0
Blood pressure	2.5
Tobacco	2.0
Cholesterol	1.9

* Disability Adjusted Life Years

Global

Risk Factor
Underweight
Unsafe sex
Tobacco
Alcohol
Unsafe water, sanitation and hygiene
Cholesterol
Indoor smoke from solid fuels
Iron deficiency
Overweight
Zinc deficiency
Low fruit and vegetable intake
Vitamin A deficiency
Physical inactivity
Risk actors for injury
Lead exposure
Illicit drugs
Unsafe health care injections
Lack of contraception
Childhood sexual abuse

Source: The World Health Report 2002

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Zinc in humans

Human metabolism:

- Biochemical pathways
- Perpetuation of genetic material
- Transcription of DNA
- Over 300 enzymes require zinc

Few extra milligrammes of zinc

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Difference between illness and good health

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Zinc to crops to humans

Theory (rice):

- 15 kg zinc/ha → +43% [Zn] in crop
- Zinc intake nearly doubled

Practice (wheat grains):

- 40kg ZnSO4
- Followed by 3 stage foliar treatment
- Zinc level in blood serum:
  - Up from 80 to 109 µgram/liter

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Conclusions

Zinc deficiency
An underestimated problem

Zinc micronutrients
Problem solving

Watermanagement
Zinc can help

Zinc rich crops
Fight human zinc deficiency