A Success Zinc Story in Turkey and HarvestZinc Project

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NATO-Zinc Project in Anatolia

(1993-1998)

Effect of Zinc Fertilization on Wheat Production in Central Anatolia

Effect of soil applications of micronutrients (5 kg ha^{-1}) on grain yield of wheat and barley. **Experiment was conducted by Mufit Kalayci in Eskisehir (YEAR 1992)**

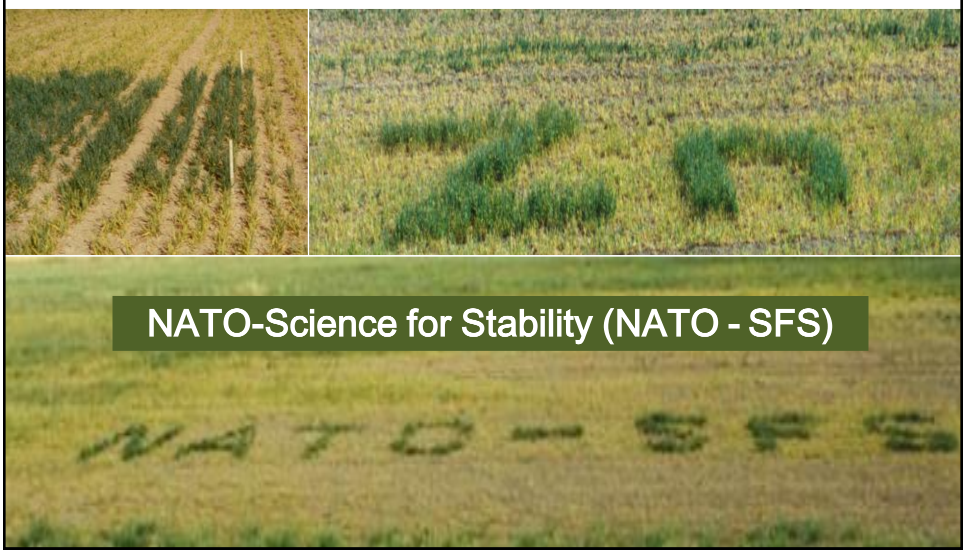
Applications	Cereals	
	Barley	Bread Wheat
	(tons ha^{-1})	
Control (all micros)	**4.73**	**4.64**
All micros **-Mn**	5.38	4.54
All micros **-Cu**	4.91	3.93
All micros **-B**	4.81	4.20
All micros **-Fe**	4.53	4.36
All micros -Zn	**3.07**	**2.96**

Cakmak et al 1998, Field Crops Res.

Pictures from NATO-Zinc Project in Central Anatolia.

Green Areas show the areas treated with Zinc Fertilizers.

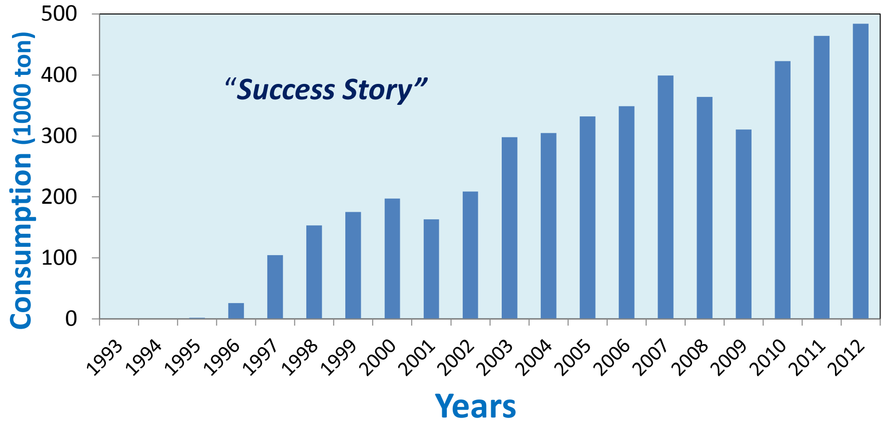
Project was supported by NATO Science for Stability Program (NATO-SFS)



Successful zinc deficiency project gets world-wide recognition

The results of a study of the reasons for zinc deficiency in wheat crops in Turkey, which was funded through the NATO Science for Stability programme in the early 1990s, are now being demonstrated at international symposia with a view to extending Turkey's experience to other areas of the world. Wheat production in Turkey at that time had very low yields, and the study aimed to identify the underlying causes and a possible link to zinc deficiency. The results of the study were spectacular, and were quickly passed on to interested parties, including Turkish farmers and the TOROS fertilizer company. Today, the total amount of zinc-containing fertilizers applied in Turkey is 300,000 tonnes, up from zero ten years ago, and Ministry of Agriculture estimates put annual economic benefits at 100 million dollars. In addition, large numbers of the Turkish population which have suffered from a diet containing too little zinc, now

Use of Zinc Containing Compound Fertilizers after NATO-Zinc Fertilizer Project in Turkey



Source: Ministry of Agriculture and Toros Fertilizer

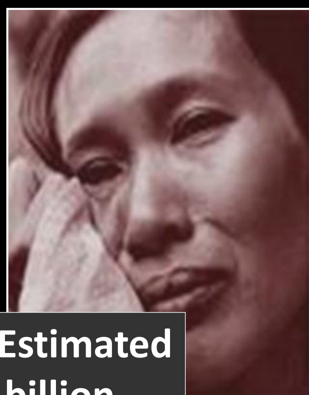
Statement of IFA

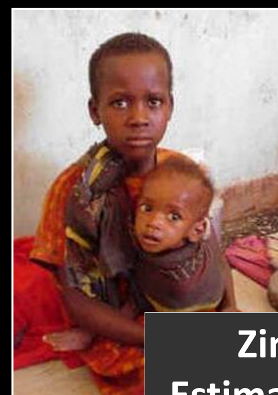
-International Fertilizer Industry Association-

12 April 2005:

"***The Anatolia initiative is one of the world's first examples of using agricultural practices to address public health problems as well as improved crop production, and its success provides a model for countless other nations***"

Zn and Fe Deficiencies: Global Malnutrition Problem





Iron Estimated 2 billion

Zinc Estimated 2 billion

www.harvestplus.org

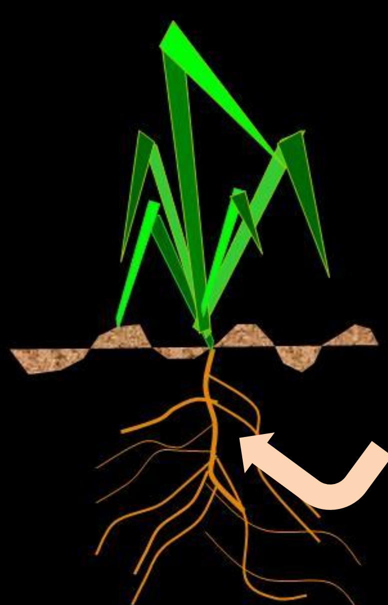
Major Reason: Low Dietary Intake

High Consumption Cereal Based Foods with Low Zn and Fe Concentrations

In number of developing countries cereals contributes nearly 75 % of the daily calorie intake.

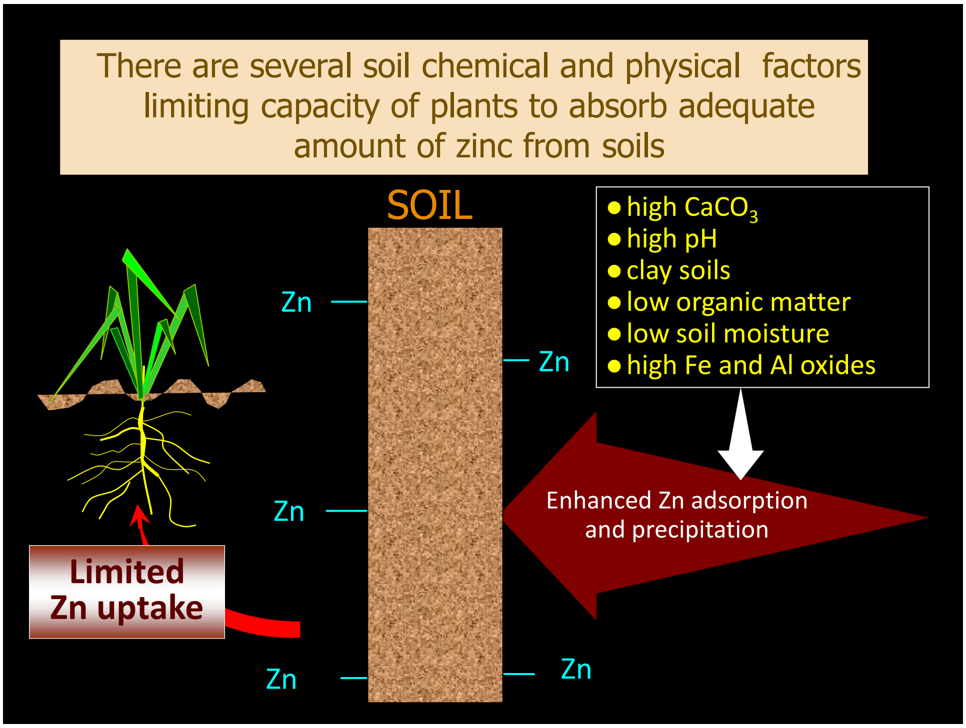
For a better Zn nutrition of human beings, cereal grains should contain around **40-60 mg Zn kg^{-1}**

Current Situation:
10-30 mg kg^{-1}



Plants are not able to synthesize mineral nutrients

Mineral nutrient must be absorbed by roots (or by leaves)



Solutions to Micronutrient Deficiencies

- Supplementation
- Food Fortification

Golden Wheat Fortfied with Zn

Agricultural Solutions
(Breeding and Fertilizer Approaches)


- Breeding

- Agronomy/Fertilizers

Complementary approaches

Rapid and Sustainable Solution

Application of Zinc Fertilizers:
(Agronomic Biofortification)

Application of Zn-containing fertilizers offers a rapid solution to the problem

Global Zinc Fertilizer Project

II. Phase

HarvestPlus
Breeding Crops for Better Nutrition

HarvestZinc
exploring fertilizer use to increase zinc in cereals

www.harvestzinc.org

Mosaic · KALI · Zinc ...essential for life · OMEX · ifa · Bayer CropScience · ADOB · Valagro · fbsciences · IPNI · ATP NUTRITION Powering Growth with Science™

Sabancı Üniversitesi

Global Zinc Fertilizer Project

HarvestPlus · HarvestZinc

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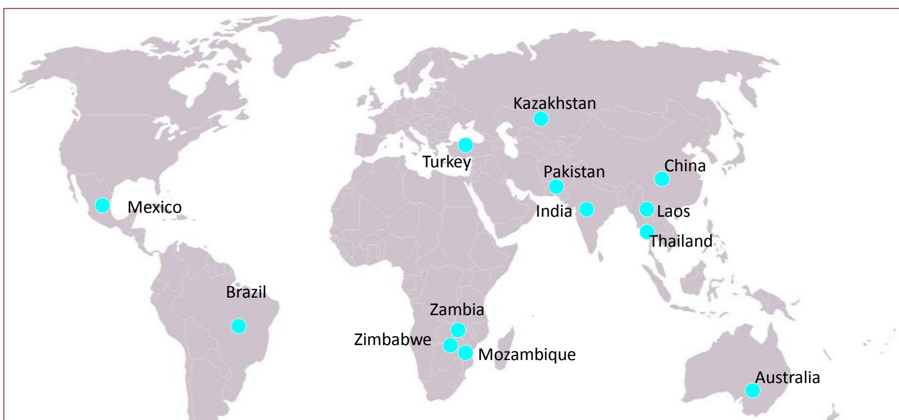

Coordinating Institution: Sabanci University

Sabancı Üniversitesi

Effect of Soil and/or Foliar Applied ZnSO4 on Grain yield and Grain Zn Concentrations in Wheat

Effect of Zn applications on wheat grain yield in 7 countries with 14 locations over 2 years

Country	Location	Harvest year	Grain yield (t ha^{-1})				F test	$LSD_{0.05}$
			Nil	Soil Zn	foliar Zn	Soil + Foliar Zn		
China	Quzhou	2009	5.4	5.4	5.4	5.6	n.s.	-
		2010	6.1	5.8	6.0	5.8	n.s.	-
	Yongshou	2009	5.0	5.0	5.0	4.9	n.s.	-
		2010	5.1	5.6	5.1	5.0	n.s.	-
India	Varanasi	2008	2.8	3.1	2.9	2.8	n.s.	-
	Kapurthala	2010	4.2	4.2	4.2	4.5	n.s.	-
		2011	4.4	4.7	4.5	4.7	n.s.	-
	Ludhiana	2010	6.8	6.7	6.4	6.3	n.s.	-
		2011	6.2	6.4	6.2	6.4	n.s.	-
Kazakhstan	Shortandy	2009	3.8	3.7	3.8	3.7	n.s.	-
		2010	1.7	1.7	1.8	1.7	n.s.	-
Mexico	Yaqui Valley	2008	7.9	7.7	8.2	7.8	n.s.	-
Pakistan	Ayub	2009	4.5	5.2	5.4	5.8	*	0.67
	Faisalabad	2008	2.2	2.7	1.7	2.2	*	0.19
	Muridke-1	2009	5.0	5.7	5.3	6.0	*	0.76
		2010	4.1	5.1	5.0	4.4	*	0.58
	Muridke-2	2009	3.7	4.3	4.1	4.5	*	0.55
		2010	3.5	3.7	4.0	4.0	*	0.25
Turkey	Eskisehir	2009	6.6	6.6	6.5	6.1	n.s.	-
		2010	4.4	4.3	4.4	4.2	n.s.	-
	Konya	2009	5.0	5.0	5.1	5.1	n.s.	-
		2010	5.5	5.6	6.1	5.2	n.s.	-
Zambia	Chisamba	2010	4.5	4.5	n.d.	4.2	n.s	-
Grand mean			4.7	4.9	4.9	4.8		
Increase (%) in grain yield over nil Zn treatment								
Mean				5.1	3.0	3.6		
Standard deviation for different trials				8.1	9.5	9.5		

Zou et al., 2012, Plant and Soil

Effect of Zn applications on wheat grain yield in 7 countries with 14 locations over 2 years

Country	Location	Harvest year	Grain yield (t ha^{-1}) Nil	Soil Zn	foliar Zn	Soil + Foliar Zn	F test	$LSD_{0.05}$
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		2010	6.1	5.8	6.0	5.8	n.s.	-
	Yongshou	2009	5.0	5.0	5.0	4.9	n.s.	-
		2010	5.1	5.6	5.1	5.0	n.s.	-
India	Varanasi	2008	2.8	3.1	2.9	2.8	n.s.	-
	Kapurthala	2010	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		2010	4.1	5.1	5.0	4.4	*	0.58
	Muridke-2	2009	3.7	4.3	4.1	4.5	*	0.55
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Increase (%) in grain yield over nil Zn treatment								
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Standard deviation for different trials				8.1	9.5	9.5		

Based on the trials in 7 countries with 14 locations over 2 years, Zn application improved grain yield by 5.1 %

Zou et al., 2012, Plant and Soil

Grain Zn concentration in different countries with and without foliar zinc fertilization

Country/Location	-Zn	+Zn
	mg kg^{-1}	
India		
•Varanasi	29	47
•PAU-I	25	81
•PAU-II	28	77
•PAU-III	26	61
•PAU-IV	49	65
•IARI	33	45
Kazakhstan		
•Loc-I	19	54
•Loc-II	28	73
Pakistan		
•Loc-I	27	48
•Loc-II	28	44
•Loc-III	30	40
•Loc-IV	29	60

Country/Location	-Zn	+Zn
	mg kg^{-1}	
Mexico		
•Year-I	21	45
•Year-II	36	60
Turkey		
•Konya	12	29
•Adana	32	57
•Samsun	23	49
•Eskisehir	22	43
China		
•Loc-I	28	54
•Loc-II	19	26
Australia		
•Loc-I	18	39
Germany		
•Average	20	32
Iran		
•Average	17	28
Brazil		
•Average	30	52

Average of all countries -Zn: 26 +Zn:50

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Grain Zn concentration in different countries with and without zinc fertilization

Country/Location	-Zn	+Zn
	mg kg^{-1}	
India		
•Varana[illegible]	[illegible]	[illegible]
•PAU-I	[illegible]	[illegible]
•PAU-II	[illegible]	[illegible]
•PAU-III	[illegible]	[illegible]
•PAU-IV	[illegible]	[illegible]
•IARI	[illegible]	[illegible]
Kazakhstan[illegible]		
•Loc-I	[illegible]	[illegible]
•Loc-II	[illegible]	[illegible]
Pakistan		
•Loc-I	[illegible]	[illegible]
•Loc-II	28	44
•Loc-III	30	40
•Loc-IV	29	60

Country/Location	-Zn	+Zn
	mg kg^{-1}	
Mexico		
•Year-I	21	45
[illegible]	36	60
[illegible]	12	29
[illegible]	32	57
[illegible]	23	49
[illegible]	22	43
[illegible]	28	54
[illegible]	19	26
[illegible]	18	39
[illegible]	20	32
Iran		
•Average	17	28
Brazil		
•Average	30	52

Average Concentrations of Grain Zn

(10 Countries with 32 locations)

-Zn: 26 ppm

+Zn: 50 ppm

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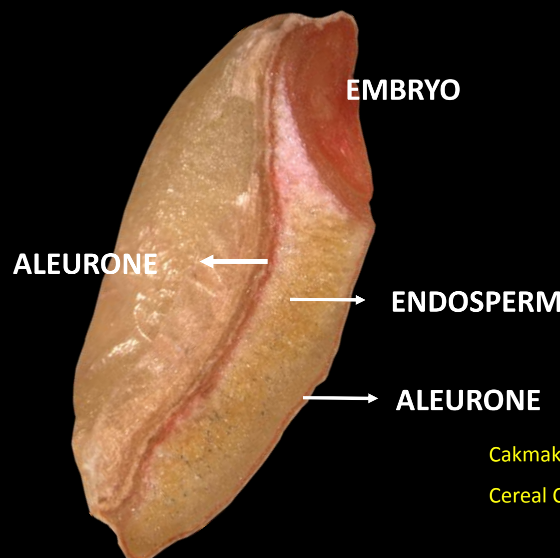
Timing of foliar Zn application

Foliar spray of Zn late in growing season results in much greater increases in grain Zn concentration when compared to the earlier applications of Zn.

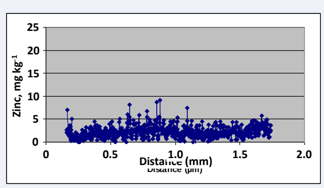
Staining/Localization of Zinc in Wheat Grain (red color)



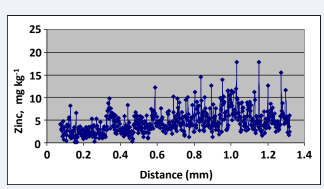
Cakmak et al., 2010

Cereal Chemistry, 77: 10-20

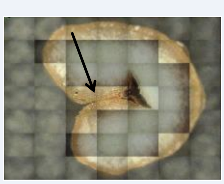
Changes in **Zinc Concentrations of Endosperm** Depending on Timing of Foliar Zinc Spray (Measurements by LA-ICP-MS)

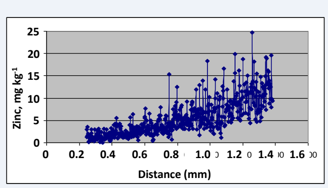


No Foliar Zn Application



Foliar Zn Spray at Stem Elongation and Booting

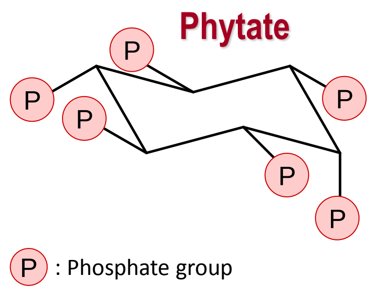




Foliar Zn Spray at Milk and Dough Stages

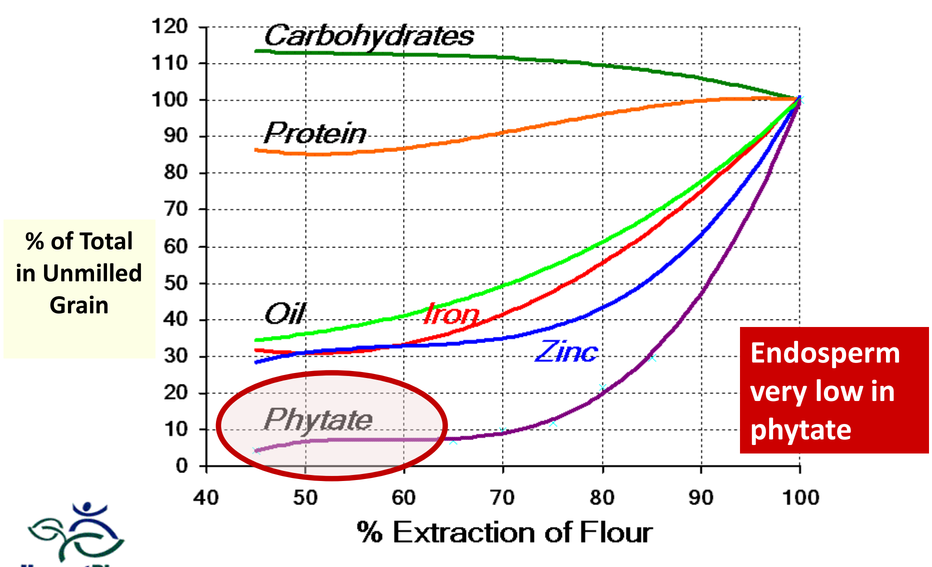
Cakmak et al 2010, J. Agric. Food Chem.

Phytate is belived to impair Zn bioavailability



- Cereal grains are rich in phytate
- Phytate forms insoluble complexes with Zn2+
- Phytate concentration is very low in endosperm

Change in Nutrient Composition With Milling Affects Bioavailability & Warrants Consideration in Breeding



Data source: Y. Pomeranz, 1978, Wheat: Chemistry and Technology, AACC.

Economy

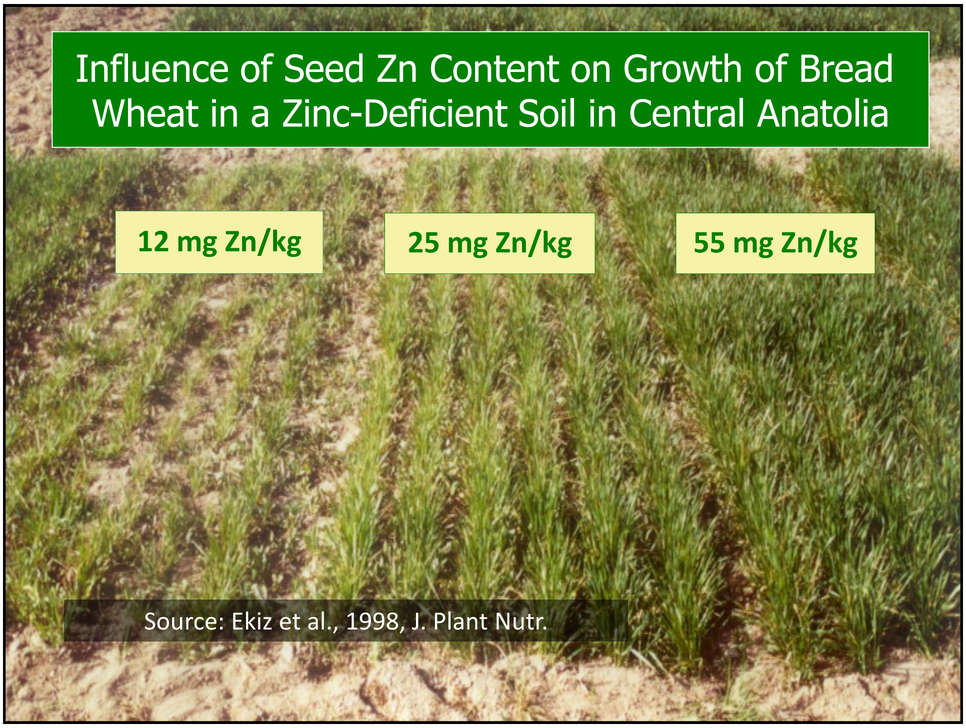
Based on the knowledge and information collected from our collaborators from Haryana, Punjab, Varanasi, Orissa and Delhi, the cost of a single spray of ZnSO4 by using power-spray ranges is around 15 USD per ha (including the costs for 4 kg ZnSO4 and the costs associated with power-spray and labor).

A yield increase of only 1.5 % (+45 kg grain) would cover the costs of foliar Zn application assuming that average grain yield is about 3 tons per ha..

Seed germination and seedling vigour improved when high Zn-seeds are used

Seed Zinc

Planting seeds with high zinc

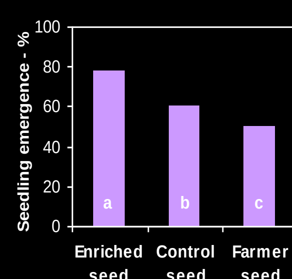


Impact of Micronutrient Dense Rice Seed in Bangladesh

(data from J. Duxbury, 2002, Cornell Univ.)

Seed Treatment	Yield (t/ha)
Complete (Zn, Mn, Cu, Mo,	4.6 a
Zn only	4.0 b
Complete - Mo	4.1 b
Control	3.6 c

[1] letters indicate significant difference at $p < 0.1$



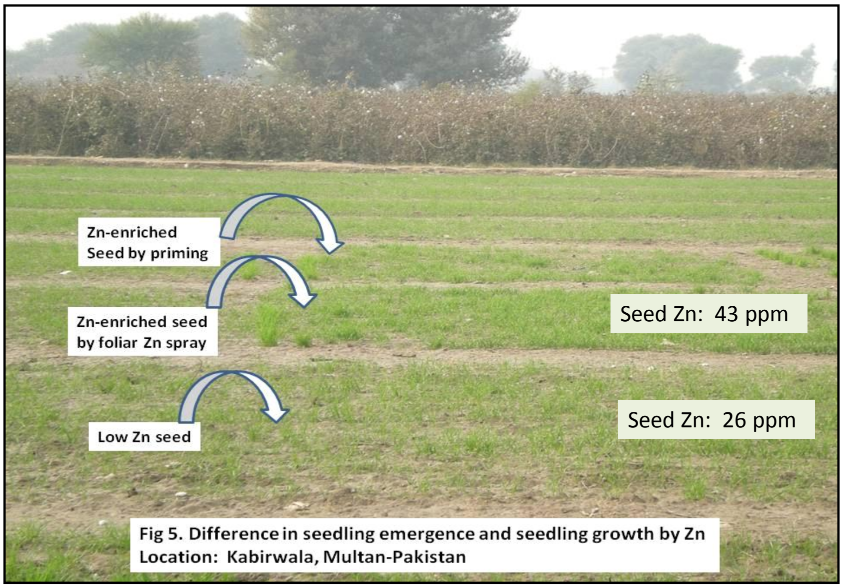
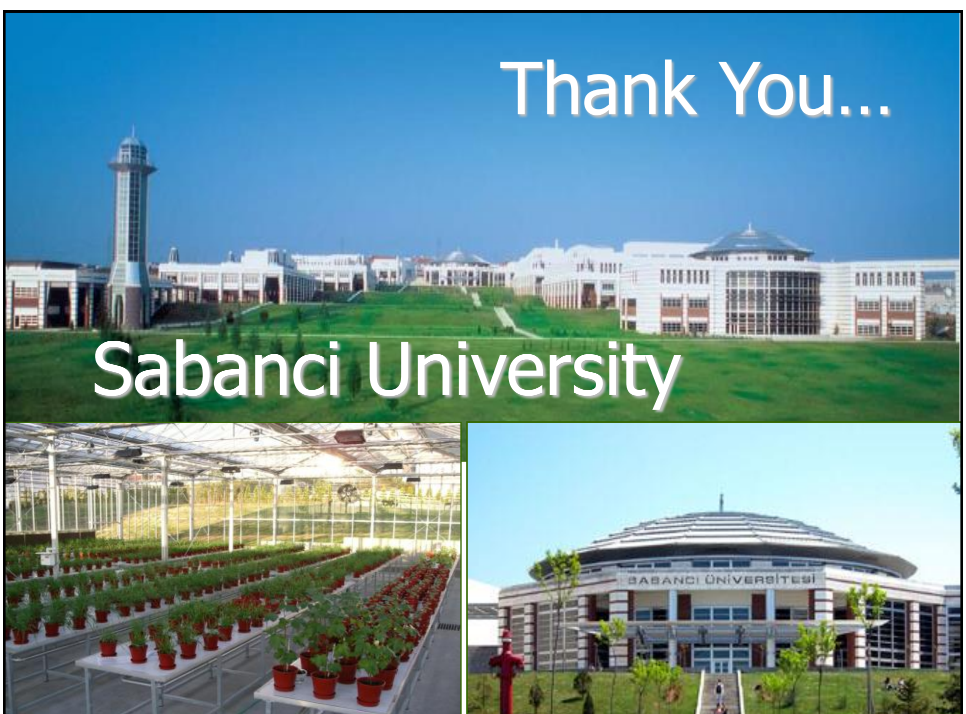


Fig 5. Difference in seedling emergence and seedling growth by Zn
Location: Kabirwala, Multan-Pakistan



Conclusion

Foliar Zn application represents a successful, rapid and cost effective practice in Zn biofortification of cereals

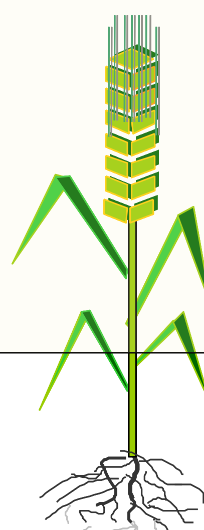
The positive impact of foliar Zn fertilization occurrs irrespective of the soil and environmental conditions, management practices and cultivars.

Foliar Zn fertilizer approach can be locally and quickly adopted for increasing dietary Zn intake in rural areas.

Nitrogen Dependent

Zinc and Iron Partitioning (%) at Maturity

Shoot Part	IRON Low N	IRON High N	ZINC Low N	ZINC High N
Husks	9	7	10	6
Grains	38	60	59	78
Leaves	48	28	17	8
Stem	5	6	14	7



Kutman et al. 2011, Plant and Soil

Localization of Protein, Zinc and Iron in Wheat Grain

Protein Zinc Iron

Cakmak et al., 2010 Cereal Chem, 77: 10-20

Staining of Protein, Zinc and Iron in Wheat Grain

Protein Zinc Iron

Cakmak et al., 2010 Cereal Chem, 77: 10-20