HarvestPlus-Zinc Fertilizer Project

HarvestZinc:

Use of Zinc-Containing Fertilizers for Enriching Cereal Grains with Zinc and Improving Yield

III. Progress Report (May 2009-November 2009)

Coordinating Institution
Sabanci University, Istanbul-Turkey

Supporting Partners

Mosaic- USA
K+S KALI GmbH-Germany
International Zinc Association-Belgium
Omex Agrifluids Ltd-UK
International Fertilizer Industry Association-France
The International Plant Nutrition Institute-USA

Collaborating Countries

BRAZIL: Agência Paulista de Tecnologia dos Agronegócios
CHINA: China Agricultural University
INDIA: Punjab Agricultural University
MOZAMBIQUE: Instituto de Investigacao Agraria de Mocambique
PAKISTAN: Pakistan Atomic Energy Commission
THAILAND: Chiang Mai University
TURKEY: Ministry of Agriculture
ZIMBABWE: University of Zimbabwe
SOFESCA: Soil Fertility Consortium for Southern Africa

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1. SUMMARY

Due to the geographical differences, only the data evaluation from wheat experiments has been completed in the northern hemisphere countries. China was the only exception completing maize and rice harvests and reporting the results, whereas rice experiments in Turkey and Thailand, and maize experiments in Turkey were just harvested and the data were not ready to present in this progress report. They will be given in the next report.

Two of the 3 collaborating countries in the southern hemisphere conduct experiments only on maize (Zimbabwe and Mozambique), while Brazil has started an additional experiment on use of foliar Zn solutions in combination with fungicides.

The collaboration with the former project partner in India had to be terminated. In order to continue trials in India, a new collaboration has been started with the Punjab Agricultural University, a long-term collaborator of the HarvestPlus Consortium in relation to the breeding program. For these reasons, and since Thailand conducts only rice experiments, focus will be given on the results from wheat experiments in Turkey, China and Pakistan, in this summary evaluation.

Wheat grain yields were not significantly affected by treatments in Turkey and China whereas they were significantly increased by application of Zn containing fertilizers in Pakistan. Rice yield was also significantly increased in China up to 10 % by Zn fertilization. What was common in all field experiments on 7 locations conducted in these 3 countries were the very distinct effect of foliar Zn applications on grain Zn concentrations, while soil applications of Zn containing fertilizers were not so effective in absence of foliar treatments. Foliar applications of Zn fertilizers highly improved grain Zn concentrations in all 3 countries. The rates of increase in grain Zn by foliar treatments alone were 104 and 69 % in the 2 experiments conducted in Turkey, whereas they were 80 and 14 % in China experiments and 78, 18, and 57 % in Pakistan. These treatment effects are graphically presented in Figure 1.

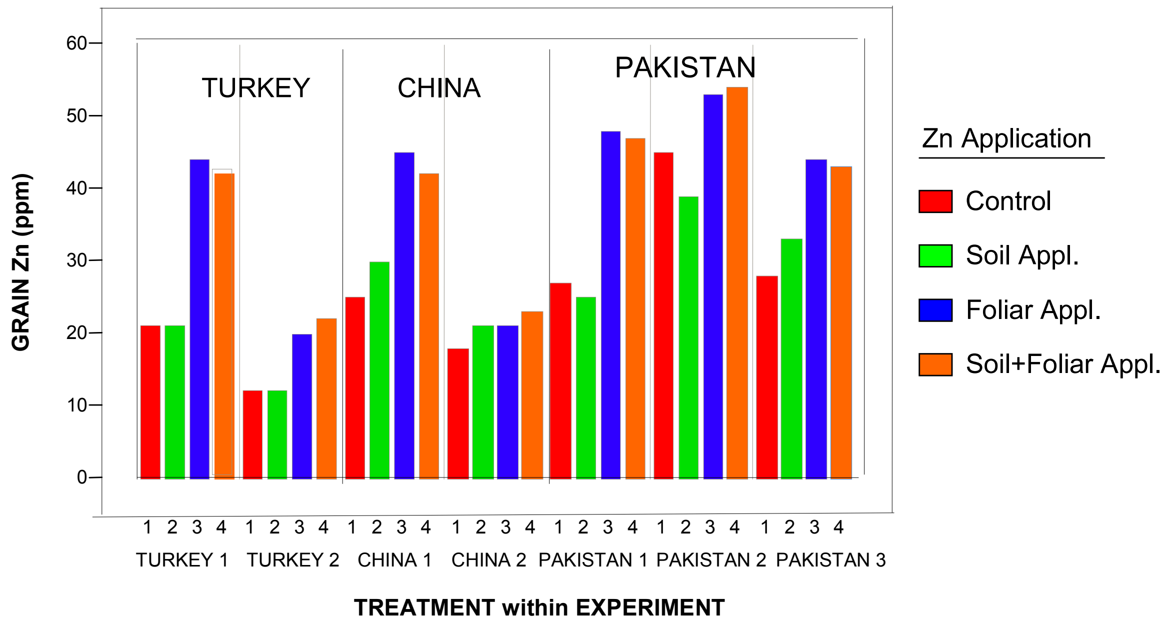

Figure 1: Effect of soil and/or foliar Zn applications on grain Zn concentration of wheat in 7 experiments conducted in 3 countries. 1: Local standard fertilizer application (no zinc); 2: Local standard + soil applied Zn; 3: Local standard + foliar Zn; 4: Local standard + soil Zn + foliar Zn. Zinc has been applied in form of $ZnSO_4.7H_2O$

In the experiments conducted with wheat in collaboration with the BASF Company in Germany (together with Dr. Gregor Pasda), foliar Zn applications resulted in an average of 60 % improvement in grain Zn concentration in 6 locations. A similar foliar Zn application test has been conducted in Australia by Dr Grahan Lyons, and the results showed an increase in grain Zn concentration over 100 % by foliar Zn applications.

When compared with the last year's results on maize and rice, which were also given in the previous report, wheat seems to be the most promising crop for increasing Zn in grains. In that aspect, maize appears to be the most difficult one of the 3 cereals. However, results from maize experiments conducted in Zimbabwe this year reveals an improvement of grain Zn by Zn treatments, again mainly by foliar applications. This brings out the question of dilution problem due to huge biomass of maize in other experiments since the yield (and biomass) levels were very low in Zimbabwe due to stresses. Consequently, whatever the reasons for this difficulty in maize are, they apparently merit further research. New maize trials have been planned to clarify the role of high biomass/grain yield of maize in grain Zn accumulation.

Another factor drawing attention was the difference between OMEX TYPE I and TYPE II foliar fertilizers. While OMEX TYPE I was not as effective as OMEX TYPE II in improving grain Zn, the latter kept causing leaf damages on maize, which was also reported from last year's maize experiments. Although the solution concentrations were reduced to 0.3 % for maize from 0.5 %, which is still used for wheat and rice, damages are reported in some countries. However, this problem seems to be observed only on maize so far. For example China, which conducts experiments with all 3 crops, reports OMEX II damage for maize but not for wheat or rice.

Zimbabwe reports promising increases in grain Zn concentrations in maize by foliar applications, but states the economical difficulties against its adoption by farmers. This should not be due to the cost of chemicals since the concentrations used are very low. If the problem results from operational costs, then the results reported for wheat from Brazil might be considered also for maize. The results in Brazilian wheat experiment shows that combining foliar Zn treatments with fungicide applications, which are almost inevitable in these tropical countries, seems to be promising if timing of treatments are rearranged to make them simultaneous with fungicide applications. This can be a good practice at least for wheat, and it might also be used for maize if grain Zn can be increased by Zn treatments in case of more reasonable yield levels. The fungicide trial conducted in Brazil will be repeated.

As mentioned before, yield results, together with grain Zn data, for maize and rice will be given in next progress report.

2. INTRODUCTION

The HarvestZinc project described here is aimed at evaluating the potential of Zn-containing fertilizers for increasing Zn concentration of cereal grains and improving crop production in different target countries including India, China, Pakistan, Thailand, Turkey, Mozambique, Zimbabwe and Brazil. These countries are characterized with high cereal production and widespread occurrence of Zn deficiency problem in plants and humans. FAO yearbook (2004) reveals the serious problem of human undernourishment in these target countries. The percent of undernourished people reaching high levels like 23, 21 and 20 % in Pakistan, Thailand and India, respectively. Considering that these percentages are below 2.5 % in industrialized countries like USA, UK and Germany, the extensive and monotonous consumption of cereal-based food plays a decisive role in widespread occurrence of Zn deficiency in these target countries.

The 4 target countries (China, India, Pakistan and Turkey) conducting the wheat experiments are among the major wheat producing countries of the world. They produce approximately one third (34.4 %) of the global wheat production from a total area of 64,396,000 ha which is close to one third of the total wheat area in the world. These countries are also among the regions where Zn deficiencies are most frequently reported both in plant and human nutrition.

Three selected countries selected for the maize trials in this project (China, Brazil and India) have a total annual maize production of nearly 180 000 million tons which is 28 % of the total global maize production. Similarly, these countries cover one third of the total maize cultivated area in the world.

Three target countries conducting rice experiments (China, India and Thailand) produce more than half (55.3 %) of the total rice production of the whole world from a total area of 82,389,000 ha (53.7 % of the world total). Rice is not only the crop having the greatest acreage but also the main staple crop used in human diets in these countries.

These three cereal crops are inherently very low in grain concentrations of micronutrients, especially Zn, and they represent major source of daily calorie intake in the developing world. The yield capacity of these cereals is very much affected from soil Zn deficiency. The objectives of this project are, therefore, i) to improve Zn nutritional status of cereal crops, ii) to increase Zn density in grain, and finally iii) to contribute to farmer's income and human health through development of practical methods for the best soil and foliar Zn fertilizer applications that will maximize the accumulation of Zn in the grain. The results obtained and management practices developed in this project will be easily transferable to other target countries as well as to other important staple food crops such as potatoes, bean and cassava.

The HarvestZinc project has been developed under HarvestPlus (www.harvestplus.org) umbrella, and is coordinated by Sabanci University (www.sabanciuniv.edu) together with the collaborating partners in the target countries.

3. PROJECT COLLABORATORS

The project activities in each country are conducted by the following collaborating partners:

BRAZIL:
Agência Paulista de Tecnologia dos Agronegócios, São Paulo
http://www.apta.sp.gov.br
Coordinator: Dr. Aildson Pereira Duarte

CHINA:
China Agricultural University, Beijing
(www.cau.edu.cn)
Coordinator: Prof. Dr. Fusuo Zhang

INDIA:
Punjab Agricultural University, Ludhiana (PUNJAB)
(Dr. Virinder Singh Sohu and Dr. Hari Ram Saharan)

MOZAMBIQUE:
Instituto de Investigacao Agraria de Mocambique, Maputo
http://www.iiam.minag.org.mz/
Coordinator: Dr. Ricardo Maria

PAKISTAN:
Pakistan Atomic Energy Commission (PAEC) Islamabad
(www.paec.net.pk)
Coordinator: Prof Dr. Abdul Rashid

THAILAND:
Chiang Mai University (www.chiangmai.ac.th)
Coordinator: Prof. Dr. Benjavan Rerkasem

TURKEY:
Ministry of Agriculture (www.tagem.gov.tr)

ZIMBABWE:
University of Zimbabwe (www.agric.uz.ac.zw)
Coordinator: Dr. Florence Mtambanengwe

SOFESCA (Soil Fertility Consortium for Southern Africa); Zimbabwe
Coordinator: Dr. Paul Mapfumo

4. FIELD TRIALS IN TARGET COUNTRIES (Country Reports)

Field trials are established on 2 or 3 different locations in each target country. The locations have been selected by the collaborating partners, but for sake of standardization, the experimental details (design etc) were planned by the coordinating institution Sabanci University, and sent to the related institutes.

Since NPK requirements of the crops are different among partner countries, the rates of N, P and, if needed, K were decided by the collaborating partners depending on the crops tested (wheat, rice and maize). The same experimental plan was established for wheat, maize and rice, since the number of treatments are the same for all 3 crops.

The experimental layout used is a standard *Randomized Complete Block Design* with 4 or 6 replications. However, randomization of treatments was done in such a way to form a layout like a Latin Square design. In the field design, in addition to 6 standard horizontal replication blocks, there also are 6 vertical complete replication blocks consisting of 2 columns in the planting direction. These vertical blocks will be used if horizontal variations in the experimental fields cause high CV values. In that case, a Latin Square analysis will be applied to distract this horizontal variation from error sums of square caused by field variation. Especially while working with micronutrients, this approach might be useful sometimes due to frequently occurring field variations.

There are 12 treatments applied in the field trials presented below. Since Zn-containing urea fertilizer from the Mosaic company (for the treatments 7 and 12) is not available for the project, in some countries, this treatment has been considered by applying urea+ZnSO4 at the corresponding rates. India used zinc-coated urea. Some experiments were conducted with 10 treatments, not replacing urea-Zn treatment. Besides, some countries, due to importation and customs problems, had to replace some of the chemicals with their alternatives. But the first 4 treatments comparing soil and foliar Zn treatments with control, using ZnSO4, was standard in all experiments.

The fertilizer treatments used in the experiments are given below. Since the descriptions are too long to be used in Tables, short names for treatments, which are used in Tables, are also given with bold letters in parentheses.

Fertilizer Treatments

1) Standard Application (Standard macronutrient applications decided by the countries themselves)
[LS –Zn]

2) Standard + Soil $ZnSO_4$ = Treatment 1 + 50 kg $ZnSO_4$ (7 mol water)/ha
[LS + Soil Zn]

3) Standard +Foliar $ZnSO_4$= Treatment 1 + $ZnSO_4$ solution (0.5 % for wheat and rice, 0.3 % for maize). No fix amount is given. Solutions are applied until most of the leaves are wet but before the runoff from leaf surfaces start)
[LS + Foliar Zn]

4) Standard + Soil $ZnSO_4$+ Foliar ZnSO4 = Treatment 1 + 50 kg $ZnSO_4$ (7 mol water)/ha + $ZnSO_4$ solution (0.5 % for wheat and rice, 0.3 % for maize)
[LS + Soil Zn + Foliar Zn]

5) Standard + OMEX-Type-I Foliar Zn = Treatment 1 + OMEX-Type-I Foliar Zn
[LS + OMEX-I]

6) Standard + OMEX-Type-II Foliar Zn = Treatment 1 + OMEX-Type-II Foliar Zn
[LS + OMEX-II]

7) Mosaic Urea-Zn + adjustments according to standard = Same rates of N, P, K but N is given as Mosaic Urea-Zn
[UREA-Zn]

8) Mosaic MESZ-Zn + adjustments according to standard = Same rates of N, P, K (Amount of Mosaic Soil MESZ-Zn to be applied is based on the location's standard P_2O_5 application. Since this amount of Mosaic also contains some amount of N, N application is completed to the local standard using other sources of N fertilizer.
[MESZ]

9) KALI Korn Kali-Zn + Standard = 100 kg Korn Kali-Zn (=40 kg K_2O/ha)* + standard N and P applications.
[KornKali]

10) KALI Korn Kali-Zn + Foliar $ZnSO_4$+ adjustments = 100 kg Korn Kali-Zn (=40 kg K_2O/ha)* + standard N and P applications + Foliar $ZnSO_4$ (as explained for treatment 3).
[KornKali + Foliar Zn]

11) Mosaic MESZ-Zn + Foliar $ZnSO_4$+ adjustments = Treatment 8 + Foliar $ZnSO_4$ (as explained for treatment 3).
[MESZ + Foliar Zn]

12) Mosaic Urea-Zn + KALI-Korn Kali-Zn +Foliar $ZnSO_4$ = Standard N and P application rates (N is applied as mosaic urea-zinc) + 100 kg Korn-Kali/ha (= 40 kg K_2O/ha)* + Foliar $ZnSO_4$ (as explained for treatment 3).
[**KornKali + Urea + Zn + Foliar Zn]**

* The rate of Korn-Kali was different in China and India where rates were determined by the collaborating partners.

Application Times

The proposed application times for different nutrients and different crops are given below:

- All P, K or Zn and/or Zn containing fertilizers are applied prior to planting and mixed with the soil)
- Application times for all foliar Zn solutions will be twice (first a week before heading (at tasseling for maize and a week before panicle initiation for rice) and the second a week after flowering (silking for maize)
- N applications are split. Half is applied at planting and the other half is applied at tillering for wheat, at onset of stem elongation for maize and before panicle initiation for rice).
- Amounts of macro nutrients have been arranged according to local standard applications.

Project activities of this term are given on a country report basis below:

5.1.1. COUNTRY REPORT -TURKEY

NATIONAL COORDINATOR:
Mufit Kalayci: Anatolian Agricultural Research Institute, Eskisehir

COORDINATING INSTITUTION:
Anatolian Agricultural Research Institute, Eskisehir

COLLABORATING INSTITUTIONS:
Anatolian Agricultural Research Institute, Eskisehir (Wheat and Maize trials)
Bahri Dagdas International Research Institute, Konya (Wheat and Maize trials)
Thrace Agricultural Research Institute, Edirne (Rice trials)

RESEARCH ASSOCIATES:
Dr. Cemal Cekic: Anatolian Agricultural Research Institute, Eskisehir,
Dr. Erdinc Savasli: Anatolian Agricultural Research Institute, Eskisehir,
Oguz Onder: Anatolian Agricultural Research Institute, Eskisehir,
Mehmet Tezel: Bahri Dagdas International Research Institute, Konya,
Zafer Arisoy: Bahri Dagdas International Research Institute, Konya,
Dr. Halil Surek:Thrace Agricultural Research Institute, Edirne,
Dr. Necmi Beser: Thrace Agricultural Research Institute, Edirne,

EXPERIMENTAL ACTIVITIES:

GENERAL INFORMATION:

Selected experimental locations in Turkey were Eskisehir and Konya (denoted by 1 on the map) in the Central Anatolian Plateau for wheat and maize, and Edirne in the Thrace area (denoted by 2) for rice (Figure 2).

These locations were selected because Central Anatolian Plateau is the critical region for Zn deficiency. The research institutes in these 2 locations have been working on Zn deficiency of wheat since early 1990's. Anatolian Agricultural Research Institute in Eskisehir is the location where first trials on zinc fertilization of wheat were started in 1992; Bahri Dagdas International Research Institute has the experimental fields with lowest levels of plant available Zn in the country. Due to semiarid nature of the region, mostly calcareous soils, high pH, low organic matter and other factors, more than half of the soils have been shown to be Zn deficient in this region. Edirne was selected for rice experiments because more than half of the national rice production is realized in the Thrace area where Edirne is located, and the Thrace Agricultural Research Institute in Edirne is the national coordination center for rice research in the country.

Of the 12 treatments involved in the experiments, 2 treatments (the 7. and 12. treatments) were discarded from experiments in Turkey since urea-Zn fertilizer was not available. In maize and wheat trials, urea plus zinc were used for replacement of these 2 treatments, and the rice trials in Edirne were established with 10 treatments instead of 12.

Since maize and rice harvests were just completed and the data was not ready for this report, results from the wheat experiments conducted in Eskisehir and Konya will be presented in this report. For maize, only the experimental activities will be reported.

Figure 2: Experimental locations shown on the map of Turkey.

WHEAT EXPERIMENTS:

EXPERIMENTAL ACTIVITIES:

October 22, 2008: Zn soil applications were performed by spraying 50 kg $ZnSO_4$ (7 mol water) ha^{-1} in related treatment plots and mixed with soil using a disc plow in Eskisehir experiment. The experiment in Eskisehir was planted using a drill. The cultivar used was Bezostaya 1. Plot dimensions were 1.2 m width (6 rows with 20 cm row space) and 5 m length. Rate of P was 80 kg P_2O_5 ha^{-1}, all of which was applied at planting. Half of the N (70 kg N ha^{-1}) was also applied at planting.

November 1, 2008: Experiment at Konya location was planted using same treatments and cultivar as explained for Eskisehir location above.

March 31, 2009: Second half of nitrogen fertilizer (70 kg N ha^{-1}) was applied at tillering stage (Zadoks 23-24) at Eskisehir location.

April 15, 2009: Second half of nitrogen fertilizer (70 kg N ha^{-1}) was applied at Konya location.

May 14, 2009: Foliar applications of Omex-I D1871 A (treatment 5) and Omex-II 1872 B (treatment 6) were performed. Concentrations were arranged to make the amount of Zn per liter of water equal to that applied in 0.5 % $ZnSO_4$.

Foliar $ZnSO_4$ applications (treatments 3, 4, 10, 11 and 12) were performed as 0.5 % $ZnSO_4$. Same first foliar applications were performed on May 21st in Konya.

A hand-held sprayer was used for foliar applications. A week before heading (just before foliar applications) leaf samples were taken and sent to Sabanci University for analyses.

June 8, 2009: Second and last foliar applications were performed at Eskisehir location. (approximately a week after flowering, as stated in the original plan).

June 16, 2009: Second and last foliar applications were performed at Konya location.

July 18, 2009: The experiment in Eskisehir was harvested. Grain samples were taken and sent to Sabanci University for analyses.

July 27, 2009: The experiment in Konya was harvested. Grain samples were taken and sent to Sabanci University for analyses.

PROBLEMS ENCOUNTERED:

Of the 12 treatments involved in the experiments, 2 (7 and 12) were discarded from experiments in Turkey since urea-Zn fertilizer was not available. In wheat and maize trials, urea + Zn treatments were used for replacement of these urea-Zn treatments.

RESULTS AND DISCUSSIONS:

GRAIN YIELDS:

Grain yields obtained in 2008-2009 wheat experiments in Eskisehir and Konya are given at Table 1.

Table 1: Effect of treatments on grain yield of winter wheat in HP project wheat trials at Eskisehir and Konya locations in 2008-2009.

TREATMENT	GRAIN YIELD (tons ha^{-1})	
	ESKISEHIR	KONYA
1- LS* -Zn	6.55	4.99
2- LS + Soil Zn	6.57	4.97
3- LS + Foliar Zn	6.49	5.13
4- LS + Soil Zn + Foliar Zn	6.09	5.11
5- LS + OMEX-I	6.55	4.94
6- LS + OMEX-II	6.21	4.87
7- UREA-Zn	6.41	5.16
8- MESZ	6.44	5.05
9- KornKali	6.42	4.98
10- KornKali + Foliar Zn	6.43	5.32
11- MESZ + Foliar Zn	6.59	5.22
12- KornKali + Urea + Zn + Foliar Zn	6.38	5.42
MEAN	**6.43**	**5.09**
LSD (0.05)	-	-
F test	n.s.	n.s.
CV (%)	5.9	9.9

*LS = Local Standard (Standard applications used by collaborating institutions in their regions)

As can be seen from the table, treatments did not affect wheat grain yields at either location. Grain yields obtained in these experiments are unexpectedly high for these locations (average long-term yield in the region: 2.2 tons/ha), particularly at Eskisehir location, since both of these sites are located in semi-arid Central Anatolian Plateau. Due to above-average precipitation during the growth season, high yields normally expected under irrigation were obtained. This was presumably the major reason for the lack of yield response to Zn application since these 2 locations are noted for having Zn deficient soils. As shown before in Central Anatolia and Australia, Zn deficiency problem is known to be aggravated in dry seasons.

Although biological yields and yield components were also taken, since there was no effect on any of them, data is not given here. Lack of treatment effect on plant growth can be seen in the photograph showing crop appearance at the start of stem elongation stage (Figure 3).

Figure 3: Crop appearance from wheat experiment conducted in Eskisehir, Turkey.

Since this project is based on the effect of soil and/or foliar Zn applications on grain Zn concentrations, as compared to standard applications, emphasis will be given to the effect of Zn on grain Zn concentrations.

NUTRIENT CONCENTRATIONS:

Effect of the treatments on Zn, Fe and P concentrations of wheat leaves at 2 locations in 2008 are shown in Table 2.

As can be seen in Table 2, none of the treatments significantly affected the leaf concentrations of Zn, Fe or P at either location. Although it is known that soil applications of Zn are less efficient in increasing plant Zn levels, as compared to foliar applications, this complete lack of response is presumed to be the result of dilution due to heavy rains and consequent huge biomasses at both locations. It is important to notice that leaf samples collected before ant foliar application of Zn fertilizers started.

Table 2: Effect of treatments on leaf Zn, Fe and P concentrations of wheat in HP project wheat trials at Eskisehir and Konya locations in 2008-2009. Leaf samples collected before the foliar applications of Zn fertilizers.

TREATMENT	LEAF NUTRIENT CONCENTRATION					
	Zn (mg kg^{-1})		Fe (mg kg^{-1})		P (%)	
	ESKISEHIR	KONYA	ESKISEHIR	KONYA	ESKISEHIR	KONYA
1- LS* -Zn	15.4	9.0	47.1	37.1	0.276	0.200
2- LS + Soil Zn	16.6	9.7	46.0	39.6	0.287	0.207
3- LS + Foliar Zn	16.1	9.6	44.6	37.1	0.277	0.212
4- LS + Soil Zn + Foliar Zn	16.8	10.0	45.8	36.1	0.284	0.201
5- LS + OMEX-I	16.0	8.9	45.2	40.8	0.282	0.220
6- LS + OMEX-II	15.6	9.5	44.2	38.7	0.277	0.220
7- UREA-Zn	15.6	8.8	45.8	39.7	0.280	0.205
8- MESZ	14.8	7.9	43.6	38.7	0.271	0.200
9- KornKali	16.3	9.0	47.9	39.3	0.278	0.209
10- KornKali + Foliar Zn	15.8	8.6	44.6	37.6	0.287	0.196
11- MESZ + Foliar Zn	15.2	9.0	43.8	39.3	0.266	0.214
12- KornKali + Urea-Zn + Foliar Zn	16.8	9.0	47.5	38.5	0.290	0.195
MEAN	**15.9**	**9.1**	**45.5**	**38.5**	**0.280**	**0.207**
LSD (0.05)	-	-	-	-	-	-
F test	n.s.	n.s.	n.s.	n.s.	n.s	n.s.
CV (%)	12.8	12.9	10.3	8.8	8.9	8.4

* LS = Local Standard (Standard applications used by collaborating institutions in their regions)

In contrast to leaf concentrations, highly significant increases were obtained in grain Zn concentrations by foliar Zn applications, as can be seen in Table 3.

Date shown in Table 3 clearly indicates the striking difference between the effects of soil and foliar Zn applications on grain Zn concentrations. Foliar applications of Zn resulted in high levels of increases in grain Zn concentrations at both locations, which was more than 100 % in Eskisehir, whereas soil applications were not effective. This difference was observed not only in $ZnSO_4$ applications but also in cases of Zn enriched fertilizers. They did not affect grain Zn concentrations in absence of foliar Zn treatments.

In order to show the big difference between the effects soil and foliar Zn applications on grain Zn concentrations, data is presented graphically in Figure 4.

Table 3: Effect of treatments on grain Zn, Fe and P concentrations of wheat in HP project wheat trials at Eskisehir and Konya locations in 2008-2009.

TREATMENT	GRAIN NUTRIENT CONCENTRATION					
	Zn (mg kg^{-1})		Fe (mg kg^{-1})		P (%)	
	ESKISEHIR	KONYA	ESKISEHIR	KONYA	ESKISEHIR	KONYA
1- LS* -Zn	21.5	11.6	33.8	39.7	0.326	0.267
2- LS + Soil Zn	21.4	11.7	33.5	38.3	0.320	0.267
3- LS + Foliar Zn	43.9	19.6	36.1	40.9	0.335	0.269
4- LS + Soil Zn + Foliar Zn	41.9	22.1	35.7	40.2	0.322	0.255
5- LS + OMEX-I	26.4	15.8	32.8	41.1	0.351	0.293
6- LS + OMEX-II	45.7	40.8	33.7	41.5	0.331	0.265
7- UREA-Zn	20.3	10.2	33.8	39.6	0.326	0.257
8- MESZ	20.4	9.3	35.0	40.2	0.334	0.276
9- KornKali	21.0	10.1	34.0	38.2	0.327	0.265
10- KornKali + Foliar Zn	45.8	20.4	37.7	41.1	0.348	0.257
11- MESZ + Foliar Zn	44.4	21.7	37.4	40.6	0.335	0.265
12- KornKali + Urea-Zn + Foliar Zn	45.5	21.6	37.7	40.9	0.316	0.263
MEAN	**33.2**	**18.0**	**35.1**	**40.2**	**0.331**	**0.267**
LSD (0.05)	4.27	3.24	-	-	-	-
F test	**	**	n.s.	n.s.	n.s.	n.s.
CV (%)	11.1	14.1	6.6	5.6	4.5	6.9

*LS = Local Standard (Standard applications used by collaborating institutions in their regions)

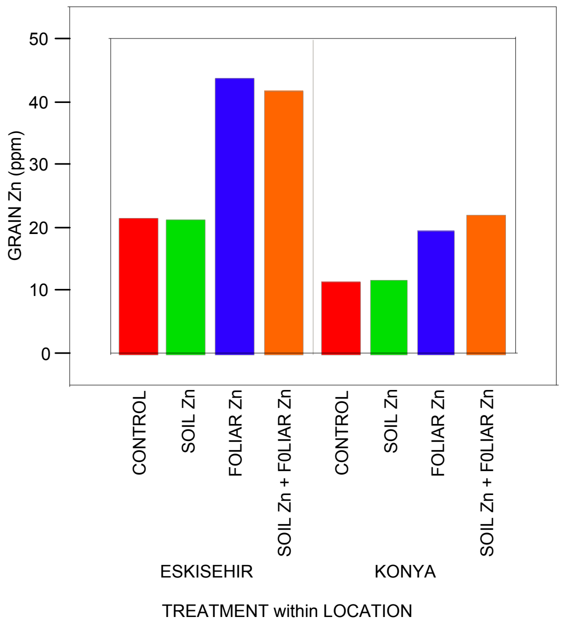

Figure 4. Effect of treatments on grain Zn, Fe and P concentrations of wheat in HP project wheat trials at Eskisehir and Konya locations in 2008-2009.

When OMEX TYPE I and TYPE II foliar solutions were compared with $ZnSO_4$, it is seen that OMEX TYPE I was not as effective as OMEX TYPE II on grain Zn concentrations at either location, whereas OMEX TYPE II was as effective as $ZnSO_4$, and even more effective at Konya location.

None of the treatments significantly affected grain Fe and P concentrations (Table 3), and other mineral nutrients (data not shown).

MAIZE EXPERIMENTS:

Two field trials were conducted with maize, at the same 2 locations with wheat experiments. Since the harvest were just completed and data were being evaluated at the time of this report, only the activities performed up to date will be given and the results will be presented in next report.

EXPERIMENTAL ACTIVITIES:

May 21, 2009: Zn soil applications were performed by spraying 50 kg $ZnSO_4$ (7 mol water) ha^{-1} in related treatment plots and mixed with soil using a disc plow in Eskisehir experiment.

May 22, 2009: The experiment in Eskisehir was planted using a pneumatic drill. The cultivar used was Pioneer 3394. Plot dimensions were 2.8 m width (4 rows with 80 cm row space) and 7.5 m length. Rate of P was 80 kg P_2O_5 ha^{-1}, all of which was applied at planting. Half of the N (100 kg N ha^{-1}) was also applied at planting.

May 23, 2009: The experiment in Eskisehir was irrigated to ensure germination and emergence.

June 1, 2009: The experiment in Konya was planted. Plot dimensions, rate and application method of P and N fertilizers were the same as Eskisehir. Zn soil applications were performed by spraying 50 kg $ZnSO_4$ (7 mol water)/ha in related treatment plots and mixed with soil using a rototiller in Konya experiment.

June 8, 2009: Thinning was performed to arrange within-row spaces at 15-20 cm. First hoeing was done. Hoeing was performed 3 times in both experiments first of which was mechanized hoeing and the rest were by hand.

June 27, 2009: Thinning was performed to arrange within-row spaces at 15-20 cm. First hoeing was done. Hoeing was performed 3 times in both experiments first of which was mechanized hoeing and the rest were by hand.

Both experiments were irrigated 5 times during the growing season including the restricted irrigation for emergence.

July 29 – September 2: Foliar applications of Omex-I D1871 A (treatment 5) and Omex-II 1872 B (treatment 6) were performed. Concentrations were arranged to make the amount of Zn per liter of water equal to that applied in 0.3 % $ZnSO_4$.

Foliar $ZnSO_4$ applications (treatments 3, 4, 10, 11 and 12) were performed as 0.3 % $ZnSO_4$. First foliar applications were performed on July 29th in Eskisehir and on August 12th in Konya.

Second applications of foliar solutions were performed at both locations one week after silking (on August 17th in Eskisehir and on September 2nd in Konya).

A hand-held sprayer was used for foliar applications.

Leaf samples were taken before foliar applications and sent to Sabanci University for analyses. Grain samples will be sent in these days since harvest is just finished.

FUTURE ACTIVITIES:

Maize experiments in Eskisehir and Konya and rice experiments in Edirne are just being harvested. Grain samples from the trials will be sent to Sabanci University for analyses. Results from these experiments will be presented in next term report.

2009-2010 wheat experiments were planted in Eskisehir and Konya in October, 2009. They will be harvested in July 2010.

5.1.2. COUNTRY REPORT-CHINA

NATIONAL COORDINATOR:
Fusuo Zhang: China Agricultural University, Beijing

COORDINATING INSTITUTION:
China Agricultural University, Beijing

COLLABORATING INSTITUTIONS:
China Agricultural University, Beijing
Northwest Agriculture and Forestry University
Zhejiang University
The Anhui Academy of Agricultural Sciences

RESEARCH ASSOCIATES:
Chunqin Zou, Fusuo Zhang: China Agricultural University
Zhaohui Wang: Northwest Agriculture and Forestry University
Lianghuan Wu: Zhejiang University
Lujiu Li: The Anhui Academy of Agricultural Sciences

PhD AND GRADUATE STUDENTS INVOLVED IN THE PROJECT ACTIVITIES:
Yueqiang Zhang, Hui Mao, Hubing Zhao, Jianwei Wang, Kerui Li etc.

EXPERIMENTAL ACTIVITIES:

GENERAL INFORMATION:

Locations of Maize, Rice and Winter Wheat Experiments in China:

The field trials were conducted in the Yongshou town in Shaanxi province and Quzhou town in Hebei province for maize, Luotang town in Anhui province and Fubu town in Zhejiang province for rice, and Yongshou town in Shaanxi province and Quzhou town in Hebei province for winter wheat in 2009 (Figure 5).

Figure 5: The experimental locations in China for Harvest Plus maize, rice and winter wheat trials in 2009.

Six trials, two for each of maize, wheat and rice were conducted in 2009. The same rice and maize cultivars were used at two different experimental locations. The cultivar Guoliangyou618 was used in the rice experiments and Zhengdan958 in the maize experiments. Yunzao2130, Kenong9204 for Yongshou and Quzhou, respectively, were used in the winter wheat experiments. Different cultivars of winter wheat were selected regarding adaptability to the ecological conditions of the test locations.

WHEAT EXPERIMENTS:

EXPERIMENTAL ACTIVITIES:

March 27, 2009: Topdressing nitrogen in Quzhou (Hebei province). 80 kg N ha^{-1} as urea was applied in all plots following irrigation of 50 mm.

March 28, 2009: Topdressing nitrogen in Yongshou (Shaanxi province). 80 kg N ha^{-1} as urea was applied in all plots.

April, 20, 2009: Leaf samples (two sections of 50 cm) were taken from the experiment in Yongshou. All the leaf samples were washed by deionized water and dried in oven at 70 ^oC. First foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed before heading. The concentration of $ZnSO_4$ solution was 0.4 %. A safener were used in OMEX Type II solutions for avoiding toxicity. A high press-sprayer was used for foliar applications. 0.01% Tween 80 was also used together with foliar applications. Some related pictures are presented in Figure 6.

Figure 6: The foliar applications at Quzhou location (A) and Fubu location (B).

April 21, 2009: Leaf samples were taken from the experiment in Quzhou. The first foliar applications of Zn solutions were performed on the same day. The method of sampling and foliar application was the same as in Yongshou.

Second foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed a week after flowering. Same methods were used as the first applications.

June 7, 2009: Harvest of the experiment in Quzhou. Plants of 4 m^2 were harvested for measuring grain yield. Fifty spikes were collected and threshed by hand for grain samples. The grain samples were washed with distilled water then dried at 70 ^oC. Grain samples were oven-dried. They have been sent to China Agricultural University and nutrient analysis of samples has been finished.

June 24, 2009: Harvest of the experiment in Yongshou. The management and preparation of samples were the same as in Quzhou.

RESULTS AND DISCUSSIONS:

GRAIN YIELDS:

The data of wheat grain yield are shown in Table 4. There was no significant effect by Zn application on wheat grain yield in either location.

Table 4: Effects of different Zn application methods on wheat grain yield at two locations (yields were adjusted for 13 % water content).

TREATMENT	GRAIN YIELD (tons ha^{-1})	
	QUZHOU	YONGSHOU
1- LS* -Zn	5.4	5.0
2- LS + Soil Zn	5.4	5.0
3- LS + Foliar Zn	5.4	5.0
4- LS + Soil Zn + Foliar Zn	5.6	4.9
5- LS + OMEX-I	5.3	5.2
6- LS + OMEX-II	5.2	5.0
7- UREA-Zn	5.6	5.1
8- MESZ	5.8	4.9
9- KornKali	5.9	4.5
10- KornKali + Foliar Zn	5.6	5.0
11- MESZ + Foliar Zn	5.6	5.2
12- KornKali + Urea + Zn + Foliar Zn	5.8	5.3
LSD (0.05)	0.53	0.41

*LS = Local Standard (Standard applications used by collaborating institutions in their regions).

NUTRIENT CONCENTRATIONS:

The nutrient concentrations of wheat grain are shown in Figure 7A (Quzhou) and 7B (Yongshou). The Zn concentration of grain showed increasing trends in all treatments of Zn application as compared to control, especially in the treatments of foliar Zn application. In general, foliar application of Zn with or without soil Zn application significantly increased grain Zn concentration rather than soil Zn fertilizer alone. Among all the treatments, the treatment of foliar $ZnSO_4.7H_2O$ application with or without Soil Zn application was most effective and stable to increase grain Zn concentration in both locations.

FUTURE ACTIVITIES:

The second year of wheat trials are being conducted at Quzhou and Yongshou stations.

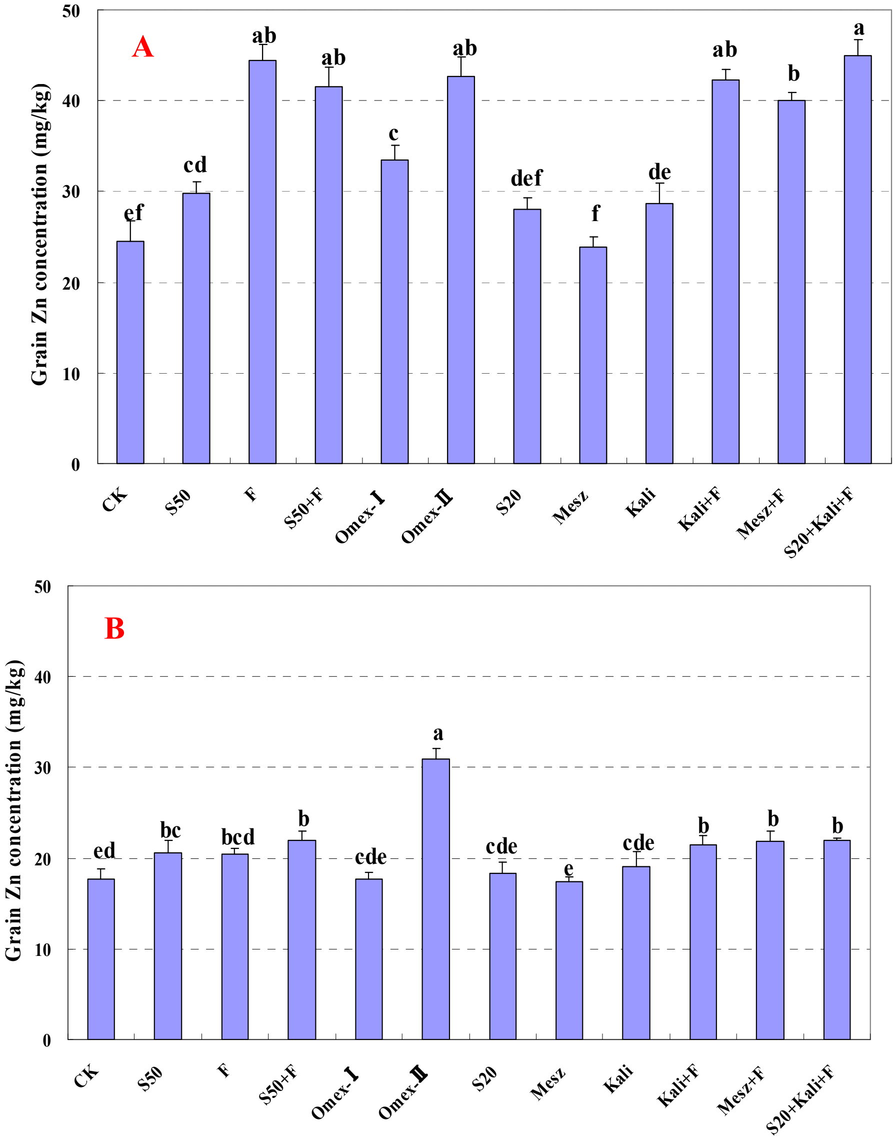

Figure 6**:** The effects of Zn application on Zn concentration of wheat grain at Quzhou (A) and Yongshou (B) in 2009.

FUTURE ACTIVITIES:

The second year of wheat trials are being conducted at Quzhou and Yongshou stations.

RICE EXPERIMENTS:

EXPERIMENTAL ACTIVITIES:

May 31, 2009: Transplanting of rice in Luotang (Anhui province). For this lowland rice trial, first the dried rice land was fertilized at the rates stated in the project. 200 kg N ha^{-1}, 80 kg

P_2O_5 ha^{-1}, and 150 kg K_2O ha^{-1} were applied before transplanting. All of P, K and Zn and half of N was used before planting except treatment 7 and treatment 12 which all of the N fertilizer were applied as urea-Zn before seed sowing. Then, the plots were plowed and flooded. Finally, rice plants were transplanted on June 1. Plot sizes were 15 m^2 at planting and 4 m^2 at harvest.

June 21, 2009: Sowing of rice in Fubu (Zhejiang province). For this lowland rice trial, first the dried rice land was fertilized at the rates stated in the project. The rates were 200 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1}, and 150 kg K_2O ha^{-1}. All of P, K and Zn and half of N was used before planting except treatment 7 and treatment 12 which all of the N fertilizer were applied as urea-Zn before seed sowing. Then the plots were plowed and flooded. Finally, rice plants were transplanted on June 22. Plot sizes were 10 m^2 at planting and 4 m^2 at harvest.

July 26, 2009: Leaf samples were taken from the trial in Luotang (Anhui).

August 17, 2009: Leaf samples were taken from the trial in Fubu (Zhejiang).

First foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed before panicle development. The concentration of $ZnSO_4$ solution was 0.5 %. A safener were used in OMEX Type II solutions for avoiding toxicity. A high press-sprayer was used for foliar applications. 0.01% Tween 80 was also used together with foliar applications.

Second foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed a week after flowering. Same methods were used as the first applications.

September 23, 2009: Harvest of the rice trial in Luotang (Anhui).

October 4, 2009: Harvest of the rice trial in Fubu (Zhejiang).

All leaf samples (2 sections of 50 cm) were washed with distilled water then dried at 70^{o}C, finally grinded by stainless steel grinder. Grain samples were threshed by hand and washed by deionized water. Samples will be sent to Sabanci University, Turkey by November and nutrient analyses will be performed.

PROBLEMS ENCOUNTERED:

The rice plants grew well. However, lodging of rice plants occurred at both locations because of continuous tempest at the end of September. It decreased the grain yields.

RESULTS AND DISCUSSIONS:

GRAIN YIELDS:

Rice grain yields are shown in Table 5. There were significant effects on rice grain yields by most of Zn application in both locations. On the average, the grain yields were 5 %, and 9 % higher with Zn applications than traditional treatment in the two locations, respectively.

FUTURE ACTIVITIES:

Presently, samples are being prepared. They will be sent to Sabanci University at the end of November.

Table 5: Effects of different Zn application methods on rice grain yield at two locations (yields were adjusted for 15 % water content).

TREATMENT	GRAIN YIELD (tons ha^{-1})	
	LUOTANG	FUBU
1- LS* -Zn	9.2	7.8
2- LS + Soil Zn	9.6	8.3
3- LS + Foliar Zn	10.0	8.3
4- LS + Soil Zn + Foliar Zn	10.0	8.6
5- LS + OMEX-I	10.1	8.6
6- LS + OMEX-II	9.6	8.5
7- UREA-Zn	9.1	8.5
8- MESZ	9.9	8.7
9- KornKali	9.6	8.5
10- KornKali + Foliar Zn	9.7	8.9
11- MESZ + Foliar Zn	9.8	8.6
12- KornKali + Urea + Zn + Foliar Zn	9.5	8.5
LSD (0.05)	0.29	0.43

*LS = Local Standard (Standard applications used by collaborating institutions in their regions).

MAIZE EXPERIMENTS:

EXPERIMENTAL ACTIVITIES:

April 18, 2009: Seed sowing of maize in Yongshou (Shaanxi province). The field preparations for trials were performed by traditional tillage in China. The fertilizers were applied after first plowing then thoroughly mixed with the soil by plow again. After that, the seed bed was prepared for sowing. 200 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1}, and 75 kg K_2O ha^{-1} were applied. All of the P, K and half of the N fertilizer were applied before seed sowing except treatment 7 and treatment 12 which all of the N fertilizer were applied as urea-Zn before seed sowing. Border rows were made after seed sowing.

June 18, 2009: Seed sowing of summer maize in Quzhou (Hebei province). The fertilizers were applied after harvesting wheat crop then thoroughly mixed with the soil by rotary tiller. The same doses of fertilizers were used as in Yongshou. Then the seeds were sown by a sower. Finally, sprinkler irrigation of 50 mm was conducted because of the dry season in North China. In both of the two trials the plot sizes were 24 m^2 at planting and 9 m^2 at harvest.

July 24, 2009: Leaf samples (5 ear leaves) were taken from the experiment in Yongshou. First foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed before tasseling. The concentration of $ZnSO_4$ solution was 0.3%. A safener were used in OMEX Type II solutions for avoiding toxicity. A high press-sprayer was used for foliar applications. 0.01% Tween 80 was also used together with foliar applications.

August 13, 2009: Leaf samples (5 ear leaves) were taken from the experiment in Quzhou. First foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed before tasseling. The method of foliar application was the same as that in Yongshou.

Second foliar applications of $ZnSO_4$ and OMEX Type I and II solutions were performed a week after silking. Same methods were used as the first applications.

October 10, 2009: Harvest of the experiment in Quzhou (Hebei). 10 cobs were taken as grain samples. The remaining maize plants were harvested by combine. Grain samples were oven-dried for calculating yield. The grain samples will be washed in deionized water and oven-dried at 70^{o}C. Samples will be sent to Sabanci University, Turkey and nutrient analyses of samples will be performed.

October 25, 2008: Harvest of the experiment in Yongshou (Shaanxi). 10 cobs were taken as grain samples. The management and preparation of samples are the same as in Quzhou.

The local and traditional management practices were applied in all trials. No irrigation was applied during the whole growth stage for spring maize except application of 500 ml water per hole at sowing in Yongshou. Two irrigations were applied just after sowing and milking stage in Quzhou because of the dry season. Pesticides (insecticides and weedicides) were applied in all trials.

Maize plants were grown normally without suffering from any unexpected severe environmental stress.

An unexpected observation was the adverse effect of Omex-II foliar Zn fertilizer in Yongshou, although the concentration had been decreased (from 0.5% to 0.3%) and safener had been used.

RESULTS AND DISCUSSIONS:

GRAIN YIELDS:

The data of yield on maize are shown in Table 6. There was no significant effect on maize grain yield due to Zn application in Quzhou location. The lower yield of treatment 6 in Quzhou seems to be caused by toxicity of the foliar Zn application using OMEX-II. However no toxicity was observed by use of by OMEX-II on rice and wheat.

FUTURE ACTIVITIES:

Samples are being prepared to be sent to Sabanci University for nutrient analyses.

Table 6: Effects of different Zn application methods on maize grain yield at two locations (yields were adjusted for 15.5 % water content).

TREATMENT	GRAIN YIELD (tons ha^{-1})	
	QUZHOU	YONGSHOU
1- LS* -Zn	8.9	8.0
2- LS + Soil Zn	8.8	8.0
3- LS + Foliar Zn	8.7	8.4
4- LS + Soil Zn + Foliar Zn	8.5	7.9
5- LS + OMEX-I	9.1	8.0
6- LS + OMEX-II	8.2	8.0
7- UREA-Zn	8.6	8.3
8- MESZ	9.3	8.2
9- KornKali	8.9	8.4
10- KornKali + Foliar Zn	8.3	8.1
11- MESZ + Foliar Zn	8.7	8.2
12- KornKali + Urea + Zn + Foliar Zn	8.9	8.7
LSD (0.05)	0.70	0.59

*LS = Local Standard (Standard applications used by collaborating institutions in their regions).

5.1.3. COUNTRY REPORT - INDIA

NATIONAL COORDINATOR:

COLLABORATING INSTITUTION:

PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA (PUNJAB) INDIA
141 004

EXPERIMENTS:
In this reporting period, rice plants were harvested and data is being evaluated. Leaf and grain samples collected from the rice trials will be analyzed soon and the results will be presented in the next report. Wheat trials have been initiated early November.

EXPERIMENTAL ACTIVITIES WITH RICE:

The field experiments have been conducted at 2 locations: PAU (Punjab Agricultural University) and Krishi Vigyan Kendra, Langroya. In the experiments, following treatments have been considered:

Treatments:
T1 : 130 kg N + 26 kg P_2O_5/ha
T2 : 130 kg N + 26 kg P_2O_5+ 50 kg $ZnSO_4.7H_2O$ ha^{-1}
T3 : 130 kg N + 26 kg P_2O_5 ha^{-1} + Foliar $ZnSO_4.7H_2O$ (twice)
T4 : 130 kg N + 26 kg P_2O_5+ 50 kg $ZnSO_4.7H_2O$ ha^{-1} + Foliar ZnSO4.7H2O (twice)
T5 : 130 kg N + 26 kg P_2O_5 ha^{-1} + OMEX-Type-I Foliar Zn (twice)
T6 : 130 kg N + 26 kg P_2O_5 ha^{-1} + OMEX-Type-II Foliar Zn (twice)
T7 : 130 kg N (thr. Zincated Urea) + 26 kg P_2O_5 ha^{-1}
T8 : 130 kg N + 26 kg P_2O_5 ha^{-1} (P_2O_5 thr. MESZ-Zn)
T9 : 130 kg N + 26 kg P_2O_5 ha^{-1} + 50 kg K_2O (K_2O thr. Korn Kali-Zn)
T10 : 130 kg N + 26 kg P_2O_5 ha^{-1} + 50 kg K2O (Korn Kali-Zn) + Foliar (0.5%) $ZnSO_4.7H_2O$ (twice)
T11 : 130 kg N + 26 kg P_2O_5 ha^{-1} (P_2O_5 thr. MESZ-Zn)+ Foliar (0.5%) $ZnSO_4.7H_2O$ (twice)
T12 : 130 kg N (thr. Zincated Urea)+ 26 kg P_2O_5 ha^{-1} + 50 kg K_2O (Korn Kali-Zn) + Foliar (0.5%) $ZnSO_4.7H_2O$ (twice)

ACTIVITIES IN RELATION TO THE RICE EXPERIMENTS:

LOCATION – I PAU, Ludhiana

The experiment was conducted with 12 treatments in four replications with plot size of 12 sqm. The rice crop variety PR 120 was transplanted on 30.06.09. The soil of the experimental field was loamy sand in texture of typically Typic Ustochrept order and Samana series at PAU, Ludhiana. The soil of the experimental field had a pH of 8.4, 0.13 mmhos/cm Electrical Conductivity, 0.45% organic matter, 15.3 kg ha^{-1} Phosphorus, 420 kg ha^{-1} Potash and 3.55 kg ha^{-1} Zinc.

LOCATION – II Krishi Vigyan Kendra, Langroya

The experiment was conducted with 12 treatments in four replications with plot size of 12 sqm. The rice crop variety PR 114 was transplanted on 18.07.09. The soil of the experimental field was loamy in texture. The soil of the experimental field had a pH of 8.9, 0.11 mmhos/cm Electrical Conductivity, 0.57 % organic matter, 15.3 kg ha^{-1} Phosphorus, 218 kg ha^{-1} ,Potash and 1.88 kg ha^{-1} Zinc.

RESULTS AND DISCUSSIONS:

GENERAL OBSERVATIONS:

LOCATION – I PAU, Ludhiana

Deficiency symptoms in rice were observed at this location at the tillering stage in no Zinc plots but later on the crop looks almost similar to the other plots with zinc. The leaf samples were collected before application of the any of the zinc treatments. Foliar application of zinc sulfate and OMEX-Type-I and Type –II had not any adverse effect on the leaves of the crop. The crop looks good but due to untimely rain at maturity stage the crop was lodged. The expected grain yield might be similar in all the treatments as there was similar crop appearance was observed. The grain samples have been collected at PAU, Ludhiana. The data on yield attributes and yield are under compilation.

LOCATION – II Krishi Vigyan Kendra, Langroya

Deficiency symptoms in rice plants were also observed at this location at the tillering stage. Foliar application of zinc sulfate and OMEX-Type-I and Type –II had not any adverse effect on the leaves of the crop. The leaf samples were also collected before application of the any of the zinc treatments. The crop looks uniform in all the plots. The expected grain yield will be possibly similar in all the treatments as similar crop appearance was observed. The data on yield attributes and yield are under compilation.

WHEAT EXPERIMENTS:

Wheat trials will be conducted at the locations of PAU, Ludhiana and RRS, Kapurthala. Experiment locations are shown on the map in Figure 7. The trial at the PAU has been already started and sown on November 6. The experiment at the Kapurthala location will be planted on November 11.

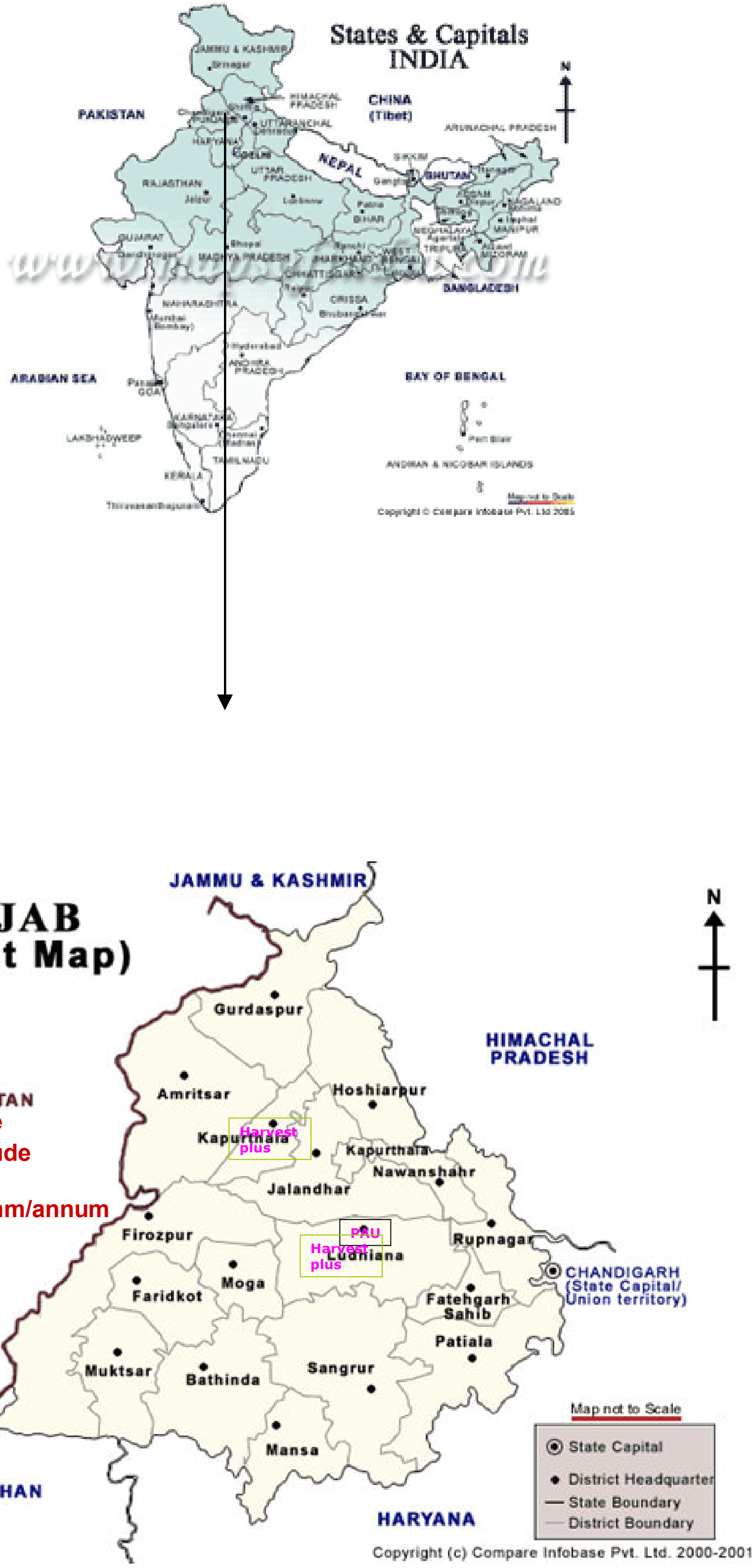

Figure 7: Maps showing experiment locations in Punjab, India.

5.1.4. COUNTRY REPORT-THAILAND

NATIONAL COORDINATOR:
Prof Dr. Benjavan Rerkasem
Agronomy Department and Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University.

COORDINATING INSTITUTION:
Agronomy Department and Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University.

COLLABORATING INSTITUTIONS:
Agronomy Department and Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University.
Rice and Commercial Crop Research Center (RCCRC) of the National Agriculture and Forestry Research Institute in Vientiane, Lao PDR.

EXPERIMENTAL ACTIVITIES:

One main experiment was conducted in Thailand, designated SITE 1 and one in Laos at the RCCRC, designated SITE 2, during the wet season (Planted in June), 2009.

One additional experiment was conducted in Thailand (T2-2009) and analyses of material and data from 2008 (SITE 1 and SITE 2 - 2008) were completed.

THE MAIN EXPERIMENTS SITE 1 AND SITE 2 - 2009:

SITE 1 and SITE 2 experiments were laid out in randomized complete block design with 10 fertilizer treatments with low earthen embankment between treatments:

1. Standard farmer application (120 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1})
2. Standard + Soil $ZnSO_4.7H_2O$
3. Standard + Foliar $ZnSO_4.7H_2O$
4. Standard + Soil $ZnSO_4.7H_2O$ + Foliar $ZnSO_4.7H_2O$
5. Standard + OMEX-Type-I Foliar Zn
6. Standard + OMEX-Type-II Foliar Zn
7. Mosaic-soil (MESZ-Zn) + adjustments according to standard
8. Mosaic-Soil (MESZ-Zn) + Foliar $ZnSO_4$ + adjustments according to standard
9. KALI-Soil (KornKali-Zn) + adjustments according to standard
10. KALI-Soil (KornKali-Zn) + Foliar $ZnSO_4$ + adjustments according to standard

Thirty-day-old seedlings were transplanted to plots (4 x 5 m each) in RCB with 6 replications. For SITE 1, each fertilizer treatment was split into subplots of two rice varieties, one with high grain Zn (RD29) and the other with low grain Zn (popular CNT1).

Foliar Zn applications were performed twice: Before panicle development and a week after flowering. The data of plant height, number of tillers and plant dry weight were taken. Leaf samples (YEB and YEB+1) were collected for nutrient analysis before foliar Zn applications at 2 times; 1) before panicle development, and 2) a week after flowering. At maturity, 1m x 1m sample of rice crop will be taken. Yield and yield components will be measured. Grain samples will be analyzed for Zn and other elements.

THE ADDITIONAL EXPERIMENT (T2-2009):

To see whether the grain Zn of rice varieties with already high grain Zn can be further elevated by foliar Zn as found in 2008, four varieties of Thai rice with high grain Zn (RD29, Namru, Sew Mae Jun and IR68144) and a low Zn but popular variety CNT1 were subjected to two Zn treatments, with and without foliar Zn (-Zn and +Zn at same rate and time as in T1-2009), in 4 replications.

TRAINING ACTIVITIES:

Two graduate students from Agronomy Department, working on the problem of iron toxicity in rice, are associated with the project to test a hypothesis that zinc may help to alleviate Fe toxicity in rice. Panonwan Boonchuay (PhD) is looking at genotypic variation in tolerance to Fe toxicity and how Zn may contribute. Panomwan's early results showed response to Zn in 3 rice varieties and no response in one variety growing in Fe-toxic soil. Singty Voradeth (MS, from RCCRC in Laos) working on management of Fe toxicity problem that includes identification and use of Fe-toxicity-tolerant varieties in combination with Zn application, foliar application and root dipping. He has completed his study and graduated with a Masters degree from Chiang Mai University.

PROBLEMS ENCOUNTERED: None

RESULTS AND DISCUSSIONS:

The results from this year's experiments will be given in next term report since they were not completed before this report.

FUTURE ACTIVITIES:
Evaluation of data from experiments conducted in 2009 will be completed.

PRESENTATION OF RESULTS:

A paper by N Phattarakul et al, entitled "Role of Zinc Fertilizers in Increasing Grain Zinc Concentration and Improving Grain Yield of Rice" was presented at the XVI International Plant Nutrition Colloquium, Sacramento, California, in August 2009.

5.1.5. COUNTRY REPORT-PAKISTAN

NATIONAL COORDINATOR:
Dr. Abdul Rashid
Chief Scientist/ Member (Biosciences)
Pakistan Atomic Energy Commission, Islamabad, Pakistan

COLLABORATING INSTITUTIONS:
Plant Breeding and Genetics Division, Nuclear Institute of Agriculture & Biology (NIAB), Faisalabad, Pakistan

RESEARCH TEAM:

Mahmood-ul-Hassan (Chief Investigator),
Senior Scientist, Plant Breeding and Genetics Division, Nuclear Institute of Agriculture & Biology (NIAB), Faisalabad, Pakistan

Dr. Zafar Iqbal, Senior Scientist,
Soil Science Division, Nuclear Institute of Agriculture & Biology, (NIAB), Faisalabad, Pakistan

Dr. Tariq Mahmood Qureshi, Senior Scientist, Soil Science Division, NIAB, Faisalabad, Pakistan

Faqir Hussain, Deputy Chief Scientist, NIAB, Faisalabad, Pakistan

SITE SELECTION AND SOIL SAMPLING:

3 field trials of Harvest Plus Zinc Project were conducted in the main rice-wheat tract of the Punjab province – where world renowned aromatic Basmati rice is grown. To be precise, these field experiments were located in district Sheikhupura (on Sheikhupura-Muridke Road), towards the north of capital city of Punjab province, Lahore (Figure 8).

The soils are alkaline silty clays, porous with weak subsoil structure, moderately well drained with few fine scattered free $CaCO_3$ nodules (Soil Survey of Pakistan, 1968). This district has extreme climate; the summer season starts from April and continues till October. During the summer season, average temperature ranges from 30 to 45^oC. The winter season starts from November and continues till March. December and January are the coldest months with a mean minimum temperature of 5^oC.

Figure 8: Experiment district shown on the map of Pakistan.

SOIL SAMPLING AND LABORATORY ANALYSIS:

Soil sampling was done by taking five representative random cores (0–30 cm depth) from each of the selected experimental fields. Using standard laboratory methods as described by Ryan et al. (2001, Soil and Plant Analysis Laboratory Manual, ICARDA), the soils were analyzed for salient physico-chemical properties. Soil Zn was determined by the DTPA method of Lindsay and Norvell (1978, SSSA, 42: 421–428.)

Table 7**:** Soil (0–30 cm) properties of three experimental field sites.

Experimental Farm	pH	EC (dS m^{-1})	Organic matter (%)	NH_4-N (mg kg^{-1})	NO_3-N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})	DTPA Zn (mg kg^{-1})
Ayub Farm	7.8	0.60	0.61	0.4	22.4	2.0	82	0.71
Shahbaz Farm	7.9	0.58	0.59	1.5	1.7	4.8	67	0.28
Basharat Farm	8.1	0.52	0.52	1.5	5.2	9.2	80	0.50

EXPERIMENTAL ACTIVITIES:

A widely adapted, rust resistant, and, popular among farmers, commercial wheat variety, i.e., Sehar-2006 was used for the experiments. This variety has very good yield potential (above 4 tons ha-1).

The selected fields were irrigated two weeks prior to rice harvest. Rice stubbles at all field sites were chopped and soil-incorporated by disc ploughing, followed by two-time cultivation and planking.

FIELD LAYOUT AND TREATMENT APPLICATIONS:

Field layout was done according to a randomized complete block experimental design, with plot size of 4 m x 9.6 m and six (6) replications.

Application of fertilizers to soil were made by manual broadcasting to the individual plots and, thereafter, incorporation within the upper 0-15 cm soil layer with the help of a tractor-mounted cultivator. Just prior to seed sowing, Stomp weedicide was applied (@ 1 L acre-1), by a manual sprayer, uniformly throughout the whole field. Sowing was done (on November 19, 2008 at Basharat and Shahbaz Farms and on November 24, 2008 on Ayub Farm) by 11 tined tractor driven wheat drill by keeping line to line spacing of 15 cm. Seed rate of 40 kg $acre^{-1}$ was used. Twenty two lines of 9.6 m length were maintained in every plot.

In the month of January, when the crop was at tillering stage, presence of narrow- and broad-leaved weeds was observed in the field. To control these weeds, two Zn-free weedicides i.e., Poma Super @ 500 mL acre-1 and Buctril Super @ 300 mL acre-1, were applied to all the experimental fields uniformly by using a hand sprayer.

The followed fertilizer application schedule both for the soil and foliar applications of Zn is given in Table 8.

Table 8: Fertilizer treatments and application schedule.

Treatments		Time of application			
No.	**Description**	**At sowing**	**At tillering**	**One week before heading**	**One week after flowering**
1- LS -Zn	Standard farmer fertilizer use = 80 kg P_2O_5 + 120 kg N ha^{-1}	Whole TSP dose + 50% Urea dose	50% Urea dose	--	--
2- LS + Soil Zn	T1 + soil $ZnSO_4.7H_2O$ = 80 kg P_2O_5 + 120 kg N + 50 kg $ZnSO_4.7H_2O$ ha^{-1}	Whole TSP dose + 50% Urea dose + Whole *$ZnSO_4.H_2O$ dose	50% Urea dose	--	--
3- LS + Foliar Zn	T1 + Foliar $ZnSO_4.7H_2O$ = 80 kg P_2O_5 + 120 kg N + 0.5 % $ZnSO_4.7H_2O$ ha^{-1}	Whole TSP dose + 50% Urea dose	50% Urea dose	**$ZnSO_4.H_2O$ (Foliar)	**$ZnSO_4.H_2O$ (Foliar)
4- LS + Soil Zn + Foliar Zn	T1 + Soil $ZnSO_4$ + Foliar $ZnSO_4$ = 80 kg P_2O_5 + 120 kg N + 50 kg $ZnSO_4.7H_2O$ + 0.5 % $ZnSO_4.7H_2O$ ha^{-1}	Whole TSP dose + 50% Urea dose + Whole *$ZnSO_4.H_2O$ dose (soil)	50% Urea dose	**$ZnSO_4.H_2O$ (Foliar)	**$ZnSO_4.H_2O$ (Foliar)
5- LS + OMEX-I	T1 + Omex-Type-I Foliar Zn = 80 kg P_2O_5 + 120 kg N ha^{-1} + Omex-Type-I Foliar Zn	Whole TSP dose + 50% Urea dose	50% Urea dose	OMEX-I Zn (Foliar)	OMEX-1 Zn (Foliar)
6- LS + OMEX-II	T1 + Omex-Type-II Foliar Zn = 80 kg P_2O_5 + 120 kg N ha^{-1} + Omex-II (Foliar Zn)	Whole TSP dose + 50% Urea dose	50% Urea dose	OMEX-II Zn (Foliar)	OMEX-II Zn (Foliar)
7- UREA-Zn	***Urea-Zn +Adjustments according to T1 = 80 kg P_2O_5 + 120 kg N + 25 kg $ZnSO_4.7H_2O$ ha^{-1}	Whole TSP dose + Whole Urea dose + Whole $ZnSO_4.H_2O$ dose (soil)	--	--	--
8- MESZ	Mosaic-soil (MESZ- Zn) + Adjustment according to T1 = 80 kg P_2O_5 + 120 kg N ha^{-1} (MESZ-Zn, based on T_1 P_2O_5 application)	Whole MESZ-Zn dose + N adjustment from Urea to complete 60 kg N ha^{-1}	50% Urea dose	--	--
9- MESZ + Foliar Zn	Mosaic-soil (MESZ-Zn) + Foliar $ZnSO_4.7H_2O$ + Adjusts = T 8 + Foliar $ZnSO_4.7H_2O$	Whole MESZ-Zn dose + N adjustment from Urea to complete 60 kg N ha^{-1} + **$ZnSO_4.H_2O$ (Foliar)	50% Urea dose	**$ZnSO_4.H_2O$ (Foliar)	**$ZnSO_4.H_2O$ (Foliar)
10- Urea Zn + Foliar Zn	***Urea-Zn + Foliar $ZnSO_4.7H_2O$ + adj. = 120 kg N ha^{-1} + 80 kg P_2O_5 + 25 kg $ZnSO_4.7H_2O$ + Foliar $ZnSO_4.7H_2O$	Whole dose of TSP, Urea and $ZnSO_4.H_2O$ (soil)	--	**$ZnSO_4.H_2O$ (Foliar)	**$ZnSO_4.H_2O$ (Foliar)

*We used $ZnSO_4.H_2O$ (33 % Zn) for maintaining the Zn level as per suggested doses
** $ZnSO_4.H_2O$ (33 % Zn) was used in place of $ZnSO_4.7H_2O$ for foliar application to maintain the rate as per suggested treatments
***Due to non-availability of Mosaic Soil Urea-Zn, application of Urea-Zn was done by applying 120 kg N ha^{-1} + 25 kg $ZnSO_4.7H_2O$ ha^{-1} + adjustment according to T1.

Nitrogen, in the form of urea, was applied to all plots (except for Urea-Zn in T7 and T10) prior to planting, in two splits. One-half N dose was applied at sowing while the other half at tillering stage after irrigating the fields. Urea was applied manually by broadcast method in such a way that fertilizer granules got imbedded in the mud, when the field soils contained high moisture content immediately after stoppage of gravitational water percolation.

Foliar fertilizer treatments were applied using a manual sprayer, Jecto, at two plant growth stages: (i) one week prior to crop heading; and (ii) one week after flowering. The sprayer tank was thoroughly washed with clean water before and after the application of every foliar treatment. After filling one-half of the tank with water, zincated fertilizer was dissolved in a small quantity of water in a plastic bucket and then poured in and mixed well within the sprayer tank. Subsequently, the tank was filled with water and mixed-thoroughly. Foliar applications of zincated fertilizer treatments were made uniformly by covering almost all the plant leaves, and stopping just before the run off of fertilizer from leaves' surface.

Leaf sampling was realized at two plant growth stages, i.e., one week before heading and one week after flowering stage – just prior to foliar Zn applications. Flag leaves of 100 randomly selected plants were collected from every treatment. The sampling was made from inner rows of every plot in order to avoid any border effect. The inner rows of every plot were harvested, threshed and grain yield was recorded and 50 g grain samples were collected from every treatment. The leaf and grain samples were oven dried at 70^{o}C. The dried grain and leaf samples were ground to 40-mesh powder in a Willy mill, and the sub-portions of ground material were digested in HNO3:HClO4 (1:1) mixture and Zn concentration in the digests was determined on atomic absorption spectrophotometer. Part of the samples has been sent to Sabanci University for further analysis. Collected data were analyzed statistically by using computer based softwares Statistix and Minitab.

RESULTS AND DISCUSSION:

Application of Zn to wheat crop on all sites, either through soil or as foliar sprays, caused increase in grain yield. Differences in crop growth and leaf color were quite obvious with control and various zincated fertilizer treatments (Figure 9). Maximum grain yield (4.0 t ha-1) was obtained with the treatment T8 where Standard + Mosaic (MESZ-Zn) was applied (Table 8). The increases in grain yield caused by soil and/or foliar application of Zn in T4 (standard + soil Zn + foliar Zn), T5 (standard + Omex-type-I, foliar Zn), T6 (Standard + Omex type-II, foliar Zn) and T9 (MESZ-Zn + Foliar Zn) were significantly higher than the standard, however, yields were statistically at par with the yields obtained with T8. Previous studies in Pakistan (Rashid and Ryan , Jour.Plant Nutr.,2004, 27: 959–975 ; and Kausar and Rashid, 2001, National Workshop, NIAB, 161-166) also support these findings.

Grain yield increases with foliar Zn applications were maximum; however in the present study best results were obtained where foliar Zn application was made, except in T8 Standard + Mosaic (MESZ-Zn) where Zn was applied to soil. Since MESZ-Zn containes 10 % sulfur which is not present in other used fertilizers, this might be a reason for the difference.

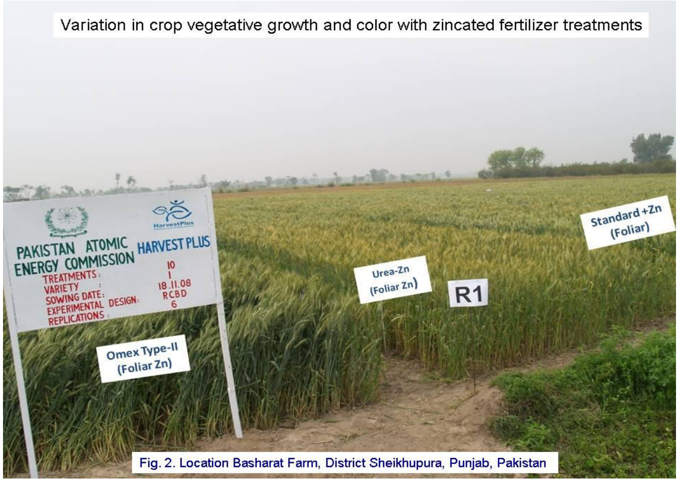

Figure 9: The experimental plots of wheat in Pakistan.

Table 9: Wheat grain yield as affected by soil/ foliar application of zincated fertilizers.

TREATMENT	GRAIN YIELD (tons ha^{-1})			
	Site 1	**Site 2**	**Site 3**	**Av. of three sites**
1- LS* -Zn	4.53 e	5.00 b	3.68 c	3.20 d
2- LS + Soil Zn	5.23 bcd	5.65 ab	4.25 ab	3.65 bc
3- LS + Foliar Zn	5.38 abcd	5.33 ab	4.11 bc	3.58 bc
4- LS + Soil Zn + Foliar Zn	5.83 ab	5.98 a	4.50 ab	3.96 a
5- LS + OMEX-I	5.61 abc	5.35 ab	4.53 ab	3.73 ab
6- LS + OMEX-II	5.18 bcde	6.00 a	4.76 a	3.81 ab
7- UREA-Zn	4.90 de	5.40 ab	4.23 abc	3.51 bc
8- MESZ	5.98 a	6.06 a	4.60 ab	4.03 a
9- MESZ + Foliar Zn	5.18 bcde	5.98 a	4.43 ab	3.76 ab
10- Urea Zn + Foliar Zn	5.00 cde	4.98 b	4.18 bc	3.41 cd
LSD (0.05)	0.67	0.76	0.55	0.31

*LS = Local Standard (Standard applications used by collaborating institutions in their regions)

Arriving at a fertilizer use strategy for improving grain Zn concentration was the main objective of the present study. Convincing results have been achieved in this study revealing significant effect of zincated fertilizers and the application technique on grain Zn concentration (Table 11). Much higher grain Zn concentrations were achieved with various Zn treatments, i.e., 48.3 mg kg^{-1} with T3 (standard + foliar Zn), 48.2 mg kg^{-1}, with T10 (Urea-Zn + foliar Zn), 47.7 mg kg^{-1} with T9 (MESZ-Zn + foliar Zn), and 47.0 mg kg^{-1} with T4 (standard + soil Zn + foliar Zn) as compared with the standard fertilizer treatment (i.e., 33.4 mg Zn kg^{-1}). Increases in Zn concentrations of leaves with soil application of Zn fertilizers were little when compared to increases in grain Zn concentrations after foliar Zn application (Tables 10 and11).

Application of appropriate rate of Zn fertilizer at crop at sowing time, along with foliar Zn application, appears to be an effective strategy for enhancing wheat productivity as well as for improving grain Zn concentration where the crop is grown in Zn deficient calcareous soils.

Table 10: Zinc concentration in wheat leaf (one week before heading) as influenced by soil application of zincated fertilizers

TREATMENT	Zn in leaf (mg kg^{-1})			
	Site 1	**Site 2**	**Site 3**	**Av. of three sites**
1- LS* -Zn	28.5 b	23.6 c	25.6 b	26.6 b
2- LS + Soil Zn	27.9 b	25.0 c	23.8 b	25.2 b
3- LS + Foliar Zn	32.7 a	23.9 c	26.7 ab	28.7 ab
4- LS + Soil Zn + Foliar Zn	30.3 ab	26.2 bc	24.4 b	26.3 b
5- LS + OMEX-I	29.7 ab	29.6 ab	26.8 ab	27.8 ab
6- LS + OMEX-II	29.5 ab	30.7 a	34.2 a	32.6 a
7- UREA-Zn	27.5 b	25.2 c	26.2 b	26.6 b
8- MESZ	28.8 b	27.0 abc	28.4 ab	28.5 ab
9- MESZ + Foliar Zn	28.5 b	29.1 ab	26.1 b	26.9 b
10- Urea Zn + Foliar Zn	27.7 b	30.0 a	26.7 ab	27.0 b
LSD (0.05)	0.67	0.76	0.55	0.76

*LS = Local Standard (Standard applications used by collaborating institutions in their regions)

Table 11: Zinc concentration in wheat grain as affected by soil/ foliar application of zincated fertilizers.

TREATMENT	**Zn in grain (mg kg^{-1})**			
	Site 1	**Site 2**	**Site 3**	**Av. of three sites**
1- LS* -Zn	27.0 c	45.3 bcde	28.0 d	33.4 c
2- LS + Soil Zn	25.3 c	38.5 e	33.2 bc	32.3 c
3- LS + Foliar Zn	48.2 a	52.6 abcd	44.1 a	48.3 a
4- LS + Soil Zn + Foliar Zn	44.6 a	53.6 abc	42.7 a	47.0 a
5- LS + OMEX-I	33.7 b	47.2 abcde	36.6 b	39.0 b
6- LS + OMEX-II	37.8 b	48.6 d	34.6 b	40.3 b
7- UREA-Zn	25.2 c	43.5 de	27.5 d	32.0 c
8- MESZ	28.1 c	44.6 cde	29.7 cd	34.1 c
9- MESZ + Foliar Zn	45.1 a	53.9 ab	44.3 a	47.7 a
10- Urea Zn + Foliar Zn	45.6 a	55.5 a	43.5 a	48.2 a
LSD (0.05)	4.34	9.25	4.57	4.17

*LS = Local Standard (Standard applications used by collaborating institutions in their regions)

5.1.6. COUNTRY REPORT-MOZAMBIQUE

NATIONAL COORDINATOR:
Maria, Ricardo. M.

RESEARCH ASSOCIATE:
Paulo Chaguala

COLLABORATING INSTITUTIONS:
Sussudenga Research Station in Central Mozambique
Umbeluzi Research Station in Southern Mozambique
Eduardo Mondlane University-Faculty of Agronomy

EXPERIMENTAL ACTIVITIES:

GENERAL INFORMATION:

Maize (Zea mays L.) is the main food crop and main cash crop of rural farmers in Mozambique. The average maize yield is about 700 kg ha^{-1}, the lowest yield of Sub-saharan Africa. Soil fertility has been indicated as main limiting factor to low soil productivity which is exacerbated by poor agronomic practices.

Zinc deficiency is one of limiting soil nutrient in some of many weathered tropical soils of Mozambique. Breeding programs were carried out for improving Zn and Fe content in selected crops, but little research has been conducted with Zn fertilizers for improving Zn content of the food crops in Mozambique.

The field experiments were conducted in the Central (Manica province) and Southern Mozambique (Umbeluzi location in the Maputo province) with contrasting biophysical conditions. In Manica the soils are physicallly good but chemically poor and the yearly average rainfall is about 1035 mm. In the case of Maputo-Umbeluzi location, the soils are physically and chemically reasonable but the yearly average rainfall is low, that is around 620 mm and not well distributed. The geographical coordinators of the experimental site in Southern Mozambique are S26 02.981 E32 22.596 and elevation 29 m asl. The predominant soil type is Luvisols. In the Manica province, the experiment had different problems in collecting data and harvesting plants at grain maturation. But, leaf samples could be collected for analysis in Turkey and data obtained shared with the researchers in Mozambique working on plant nutritional problems.

ACTIVITIES IN RELATION TO EXPERIMENTS:

SOIL SAMPLING AND LABORATORY ANALYSES:

Composite soil samples were collected using soil auger from surface layer (0-20 cm) and subsurface (20-40 cm). The sample sites were georeferenced with GPS Garmin IV. Soil samples were analyzed for particle size and chemical properties (CEC, pH, EC, OM), exchangeable cation at the IIAM Soil Central Laboratory. Due to lack of capacity in Mozambique soil laboratory, the concentrations of the micronutrients could not be analysed. Table 12 below shows a summary of selected soil properties in the experimental sites.

Table 12: Selected soil properties in the experimental sites in Manica and Umbeluzi locations.

Location	pH	P	K	Ca	Mg	ECEC	MO	Sand	Silt	Clay
		mg kg^{-1}	-----Cmol(+)/Kg solo ---------				-----------------%---------------			
Manica	6.21	16.49	1.24	20.5	6.7	28.59	4.58	42	30	28
Umbeluzi	6.40	46.00	0.70	7.0	3.7	-	1.59	65	18	16

EXPERMENTAL DESIGN AND TREATMENTS:

The experimental design used was a randomized complete block with 6 replications.

The following treatments were tested: 1) Standard application (60 kg P2O5 ha^{-1} + 80 kg N ha^{-1}); 2) Standard application + 50 kg Kg ha^{-1} of KornKali-Zn, 3) Standard + Foliar ZnSO4. + 0.5 % ZnSO4.7H2O); 4) Standard + OMEX-Type-I Foliar, 5) Standard + OMEX-Type-II Foliar Zn, 6) Urea–Zn adjusted according to standard; 7) Mosaic-soil (MESZ-Zn) + adjustments according to standard; 8) Mosaic-Soil (MESZ-Zn) + Foliar ZnSO4.

Several techniques were used for testing the effect of fertilizer and method of application on maize crop yield with GenStat and Statix8 analytical software ver.9. Analysis of variance and comparison of means were performed for testing the differences among means of treatments. Soil samples were collected prior to the establishment of the experiment, and these samples together with the grain samples, will be sent to Sabanci University in Istanbul for analysis.

RESULTS AND DISCUSSION:

Results of maize response to fertilizer application showed no statistical difference among the treatments (Table 13). The highest yield was obtained from the treatment with the Mosaic-MESZ + foliar Zn application. Interestingly, the lowest yield was observed with the Mosaic-MESZ application (without foliar Zn application) and with the Omex-Type II foliar application (Table 13). The average maize yield in unfertilized plot was 2.5 tons ha^{1}, approximately 13 % lower than the average yield observed with standard fertilizer application (2.8 tons ha^{-1}). Application of foliar zinc fertilizer shows no significant effect on maize yield when compared with standard fertilizer application.

T-test between OMEX-Type–I and OMEX-Type–II indicated no statistically significant difference (p=0.72). However, the average maize yield observed with OMEX-Type–I was 2.4 tons ha^{-1}, approximately 10 % higher than the average yield observed with OMEX-Type–II (2.2 tons ha^{-1}). The reason of such difference is unclear. In the trials conducted in the Central Mozambique, plants showed some leaf damage after application of Omex Type-II foliar treatment. These leaf symptoms were related to application of foliar fertilizers under intensive sunshine. The grain yield was not sufficiently high, as expected. In this location there was a significant incidence of the bird attack that might be one important reason for the low yield and high coefficient of variation in this location. Irregular water supply due to lack of water pump for supplementary irrigation could be a further reason for the low yield at the Umbeluzi location.

In conclusion, in contrast to the expectations, there was no positive response to Zn fertilization in the Southern Mozambique (Umbeluzi location). In the second year trials on 2 locations, the role of Zn fertilization will be more reliably evaluated. It is important to mention that, with these Zn trials Zn fertilization experiments have been conducted for the first time in Mozambique. These trials provided number of valuable experiences for the scientists involved in the trials in both locations in Mozambique.

Table 13: Average values of maize grain yield found at the Umbeluzi location (Southern Mozambique.)

TREATMENT	GRAIN YIELD (tons ha^{-1})
1) Standard application (60 kg P2O5 /ha + 80 kg N/ha)	2.4†
2) Standard + (50 kg Kg/ha of KornKali-Zn)	2.8
3) Standard + Foliar 0.5 % ZnSO4.7H2O	2.4
4) Standard + OMEX-Type-I Foliar Zn	2.4
5) Standard + OMEX-Type-II Foliar Zn	2.2
6) Urea –Zn adjusted according to standard	2.4
7) Mosaic-soil (MESZ-Zn) + adjustments according to standard	2.2
8) Mosaic-Soil (MESZ-Zn) + Foliar ZnSO4	3.2
CV (%)	57.7

† No statistical difference among treatments

FUTURE ACTIVITIES:

In the next cropping season, same trials will be established on-farm in the locations of the Central and Northern Mozambique where an important soil fertility decline problem exists. In the next trials, besides maize, also, sorghum and bean will be used as additional crops due to their importance as both food and cash crops for smallholder farmers. The grain and soil samples collected will be analyzed for Zn concentrations.

5.1.7. COUNTRY REPORT-ZIMBABWE

NATIONAL COORDINATOR:
Dr Florence Mtambanengwe

COORDINATING INSTITUTION:
University of Zimbabwe

COLLABORATING INSTITUTIONS:
National Agricultural extension services (AGRITEX) department of the Zimbabwe's Ministry of Agriculture

Soil Fertility Consortium for Southern Africa (SOFECSA).

The local extension officers were instrumental in the project implementation in the two study sites.

INTRODUCTION:

Zimbabwe has an economy that is agro-based but challenges associated with multiple nutrient deficiencies are widespread on the granite-derived sandy soils (Grant, 1981). While they were good appraisals of the state of Zn in arable soils in Zimbabwe, previous studies carried out in Zimbabwe did not adequately explore the potential of application of different fertilizers to alleviate Zn deficiency on smallholder farms and enhance plant and human nutrition.

EXPERIMENTAL ACTIVITIES:

SITE SELECTION:

In order to explore the potential of application of different fertilizers to alleviate Zn deficiency in the smallholder farms and improve Zn nutrition, two communal areas were selected for the Harvest Plus Zn project. These are Wedza and Makoni in central-east Zimbabwe. Wedza is in natural region IIb and III and receives an annual precipitation ranging from 600 – 900 mm per annum with most rainfall falling between November and March. Makoni is in natural region III and receives an annual rainfall ranging from 650 – 750 mm.

LAND PREPARATION, PLANTING AND BASAL FERTILIZER APPLICATION:

Conventional tillage was used as method of land preparation before the onset of rains using an ox-drawn mould board plough at Chikodzo and Muzondo sites. The experimental layout was a Randomized Complete Block Design (RCBD) with six replications. Randomization of treatments was done in such a way to form a Latin Square Design (LSD), as in the original protocol. There are six standard horizontal replication blocks and six vertical complete replication blocks consisting of two columns in the planting direction. Pegging of plots was done with each plot having an area of 14.4 m^2 (3.6 x 4) giving a gross area of 1 036 m^2 for the 72 plots (12 plots per block multiplied by 6 blocks). Basal application of P, K, and Zn fertilizers was done prior to planting through broadcasting and mixed with the soil.

An early-medium maturity maize cultivar (SC 513) was planted at 2 seeds per station to ensure 100 % plant stand, then thinned to one plant per station at 2 weeks after emergence (WAE). Recommended inter and intra row spacing of (0.9 m x 0.3 m) was used to achieve a plant population of approximately 37 000 plants ha^{-1}. Nitrogen was applied in 3 splits, at 4

WAE (17 January), at 6 WAE (13) and at silking (4 March). Weeding was done manually using hoes, resulting in effective control of weeds throughout the growing period. Maize stalk borer was also effectively controlled through *thionex* (2.5% Carbaryl) application. Above ground maize biomass was determined at 4 WAE by randomly up-rooting 10 maize plants per plot. The first maize leaf samples for Zn analysis were collected at 8 WAE and before any foliar application. Ten leaves were collected from each plot and placed in a well labeled khaki pack to avoid rotting. The samples were air dried and later oven dried at 60°C. Samples were ground and put in plastic containers ready for analysis. Care was taken not to contaminate the samples with any Zn containing material.

Foliar fertilizers were applied in respective plots at tasselling and a week after silking using a knap sack sprayer until the leaves were dripping wet. The treatment structure is as shown in Table 14. A compound fertilizer containing PKS nutrients, and ammonium nitrate (AN) were applied to achieve the standard nutrient application rates of 26 kg P ha^{-1} and 120 kg N ha^{-1}. Compound Z contains 1% Zn. Details concerning the fertilizer formulations are shown in Table 15.

Table 14: Treatment structure for the Zn fertilizer experiment during the 2008-2009 growing season in Zimbabwe. PKS: Phosphorus, potassium and sulphur containing compound fertilizer; AN: Ammonium nitrate.

Treatment	***Fertilizers added***
1	Compound PKS + AN
2	Compound PKS + soil ZnO + AN
3	Compound PKS + AN + foliar $ZnSO_4.7H_2O$
4	Compound PKS + soil ZnO +AN **+** foliar $ZnSO_4.7H_2O$
5	Compound PKS + AN + OMEX Type 1 foliar Zn
6	Compound PKS + AN + OMEX Type 2 foliar Zn
7	Compound Z +AN
8	Compound PKS + MESZ-Zn +AN
9	Compound PKS + Compound Z +AN
10	Compound PKS + Compound Z+AN + foliar $ZnSO_4.7H_2O$
11	Compound PKS + MESZ +AN + foliar $ZnSO_4.7H_2O$
12	Compound PKS + Compound Z + soil ZnO +AN

Table 15: Formulations and elemental composition of different fertilizers used in the Zn experiment in Zimbabwe

Form (Compound)	***Element***	***Content (%)***
NH_4NO_3	N	34.5
Compound PKS	P_2O_5	32
ZnO	Zn	78
MESZ	Zn	1.03
Compound Z	Zn	1
$ZnSO_4.7H_2O$	Zn	22
OMEX 1	Zn	6.2
OMEX 2	Zn	27

Some changes were introduced to the treatments due to non-availability of some fertilizers indicated in the original protocol. For example, $ZnSO_4$ was only obtained in January, well after crop establishment, resulting in the use of the less soluble ZnO as the basal soil Zn fertilizer in treatments 2 and 4. The rest of the changes done are presented in Table 16.

Table 16: Changes in the treatment structure

Treatment	*Original set-up*	*Actual used*
2	Standard + soil $ZnSO_4$.7H2O	Standard + soil ZnO
4	Standard + soil $ZnSO_4$.7H2O	Standard + soil ZnO
7	Mosaic Zn (Urea ZN)	Compound Z
9	Standard + KornKali - Zn	Compound Z + PKS
10	Standard + KornKali – Zn + foliar $ZnSO_4$	Compound Z + PKS + foliar $ZnSO_4$
12	Urea Zn + KornKali + foliar $ZnSO_4$	PKS + AN + soil ZnO + Compoud Z

TRAINING ACTIVITIES:

Two MSc students have been engaged on the zinc project. One of the students (Mr Takesure Tendayi) is mainly analyzing the distribution of Zn in the smallholder farms as influenced by soil type and how differential management of different land parcels influences Zn availability. The second student (Grace Manzeke) is the principal student taking detailed measurements in the experiments that were set up. Her proposed thesis title is: *Evaluating different Zinc fertilizer formulations for improved nutrition in smallholder maize production in Zimbabwe*. The students have had hands on training related to appropriate foliar application and methods of soil and foliar Zn analysis.
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PROBLEMS ENCOUNTERED:
The experimental site in Makoni district (Chikodzo site) had to be abandoned as it was affected by water logging after incessant rains during the month of January and February 2009. Samples were collected only at 4 WAE. Thereafter, no more fertilizer applications could be carried out in the plots as all treatments were affected by too much soil water. Samples were collected from this field at 8 weeks (treatments 1, 4, 7 and 11 from all blocks) so as to find the effect of water logging on Zn uptake. Control samples were collected from 2 different farmers (Chikodzo and Mhiripiri) for comparison purposes (Zn uptake in non water logged fields even though they had not received any specific Zn fertilizers).

At the site in Wedza, where all operations were carried out as planned, foliar application of OMEX 2 resulted in 'fertilizer burns' to all the six plots that received this foliar application. Graying patches were noticed on maize leaves a day after the OMEX 2 foliar application. Within 3 days, the maize plants had lost their viability. No grain yields were obtained from these plots. We are yet to understand the toxic action resulted from the application of OMEX 2.

RESULTS AND DISCUSSİON:

MAIZE PRODUCTIVITY:

Treatment differences were apparent as early as at 2 weeks after crop emergence at the two sites. Stripping consistent with Zn deficiency could be seen on young leaves of maize where no Zn had been applied basally. A photograph and a figure showing this effect were given in the previous report. This deficiency continued through the vegetative stage.

Maize yields were poor at Chikodzo experimental site, due to problems of water logging already alluded to, with no significant maize grain yield differences among the treatments (Figure 10a). No foliar fertilizers were applied later to the respective treatments as access to the field was restricted by excessive soil water.

At the second site in Wedza, grain yields were mostly above 2 t ha^{-1}, except for treatments 4 and 6. Significant maize grain yield differences were observed ($p<0.05$). Treatment 6 had the lowest maize grain yields (lower than the control treatment) due to foliar burning after application foliar fertilizer (OMEX 2). Treatments 7, 9 and 12 had the highest maize grain yields (4.67, 4.41 and 4.74 tons ha^{-1} respectively). In treatment 4, Zn was supplied through the relatively insoluble ZnO in the absence of Zn sulfate or any other soluble Zn source.

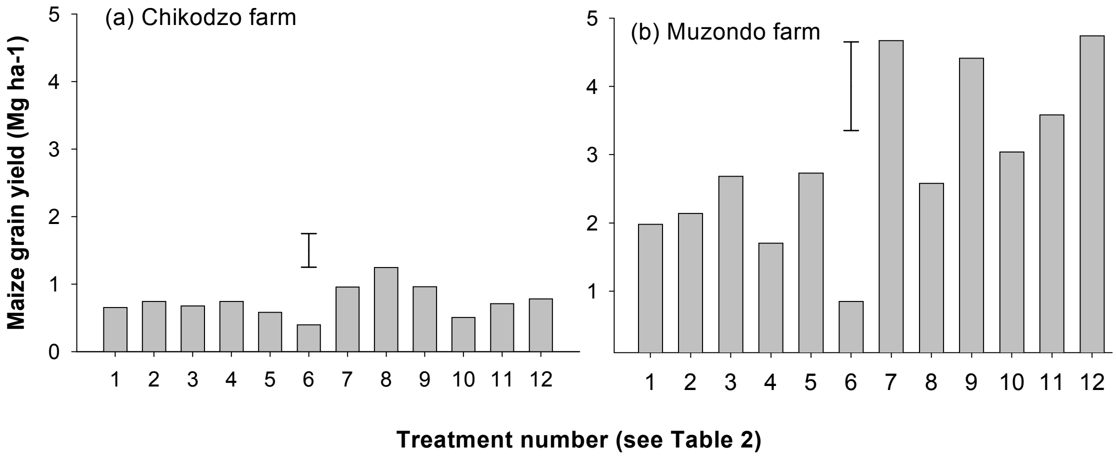

Figure 10: Maize grain yields (Mg ha^{-1}) at (a) Chikodzo and (b) Muzondo farm sites.

ZINC CONCENTRATION IN MAIZE EAR LEAF:

The cob leaf (ear leaf) is known to be the largest sink of nutrients during plant growth. These nutrients are later redistributed to the fruit (cob) as it develops. Results from maize ear leaf analysis showed treatment 12 with the highest concentration of Zn at 51 mg kg^{-1}, while treatment 5 had the least Zn concentration at 16 mg kg^{-1} (Figure 11). A number of treatments were not significantly different from the control (where Zn was not added).

ZINC CONCENTRATION IN MAIZE GRAIN:

The concentration of Zn in maize grain was lowest in the treatment that did not receive any Zn fertilizer at Muzondo site (Figure 12a). The other site that was affected by water logging had several distortions, with results in many cases contrasting those from the other site (Figure 12b). Zinc concentration ranged from 16 mg kg^{-1} in the control to 30 in treatment 4 (Compound PKS + soil ZnO +AN + foliar $ZnSO_4$). Evidently there was marked increase in maize grain Zn concentration through application of the different fertilizer formulations, but their widespread use in smallholder farming systems will be determined by their availability and affordability. Many promising technologies have failed to make an impact as adoption levels have remained low despite the seemingly convincing experimental results.

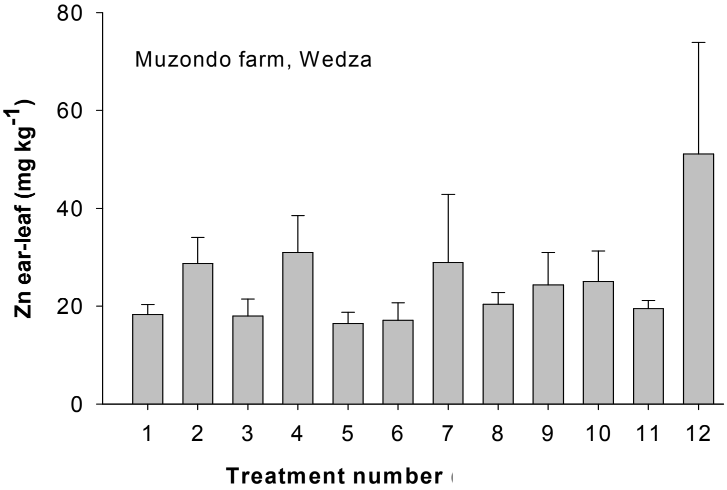

Figure 11: Zn ear-leaf concentration as influenced by different fertilizer treatments at Muzondo farm, Wedza district.

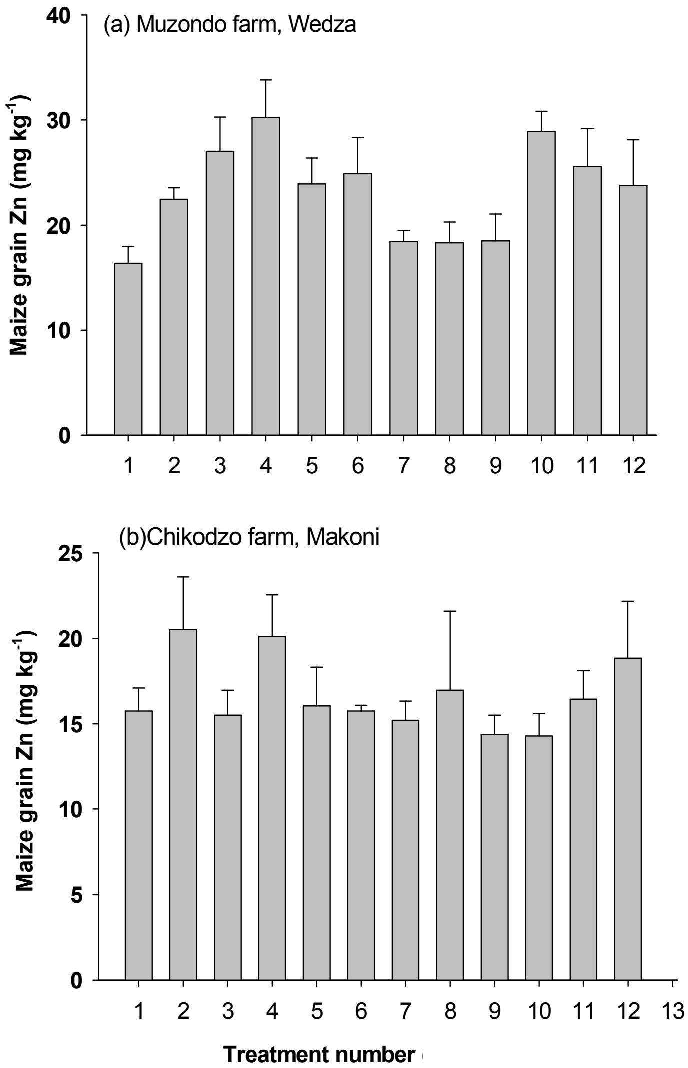

Figure 12: Zn concentration in maize grain as influenced by different treatments at (a) Muzondo farm, Wedza and (b) Chikodzo farm, Makoni district, in Zimbabwe.

CONTRIBUTIONS OF STUDENTS

The project is supporting 2 MSc students who are now getting into their second year, during which they will finalise their theses. We have developed good rapport with the farmer groups that have been hosting the 2 experimental sites. Funding of this project into year 2 will enable the research team to complete some outstanding research questions on Zn as well as tackle the emerging issues.

ACKNOWLEDGEMENTS:

The SOFECSA-Zimbabwe team together with the University of Zimbabwe acknowledges Sabanci University and SOFECSA Coordination Unit for availing funds for implementation of project activities. We also extend our gratitude to the field personnel from the Department of Agricultural Research and Extension Services (AGRITEX) of the Ministry of Agriculture in Zimbabwe and farmers in Wedza (Mashonaland East Province) and Chinyika (Manicaland Province) for their support.

5.1.8. COUNTRY REPORT-BRAZIL

NATIONAL COORDINATOR:
Aildson Pereira Daurte
Agência Paulista de Tecnologia dos Agronegócios

COORDINATING INSTITUTION:
Agência Paulista de Tecnologia dos Agronegócios

RESEARCH ASSOCIATES:
Waldir Josué Ramos – Apta, Itararé (Maize Trials)
Edison Ulisses Ramos Junior – Apta, Capão Bonito, Brazil. (Wheat Trials)

MAIZE EXPERIMENTS:

EXPERIMENTAL ACTIVITIES:

Two Harvestplus Zinc Fertilizer experiments were conducted in Sao Paulo State, Brazil. Experimental locations include sandy textured Oxisol soil in Assis (S $22^0$39' W$50^0$24', 550 m elevation) and sandy textured Oxisol soil in Itararé (S $24^0$16' W$49^0$13', 1200 m elevation), both acidic soils. The climate of the region, according to the Koppen's classification, is Cwf: subtropical with a rainy summer and wet winter. The trials were planted in January (Table 17). The genotype used was AL Bandeirante, a variety with a short season cycle and semi-flint grain texture that is used by small farmers. This cultivar was classified as Zn-efficient and responsive by Furlani et al. (2005; Scientia Agricola, Piracicaba, .62: 264-273). Seeds were treated with tiametoxam insecticide (Cruizer 350 FS, Syngenta).

Table 17: Dates of the main activities at the Assis and Itararé trials, São Paulo State.

[redacted]

The experimental design was randomized complete block with 6 replications. For yield analysis only 5 replications were used in Assis. Experimental plots had four rows, 80 cm wide (3.6 m) and 7.0 m long. Plots were over seeded and thinned at the 6-leaf stage to 55000 plants ha^{-1}. Weed control was done by use of atrazine herbicide application (Assis) or manual weeding (Itararé).

The soil was fertilized with high phosphorus doses because of the low fertility. Nitrogen at 60 kg ha^{-1} rate was side dressed as ammonium sulfate (Assis) or urea (Itararé) at the 6 to 8-leaf stage. The total N doses (planting and side dress) were 86 kg ha^{-1}. Because the customs problems with importation, Omex foliar fertilizers and Kali (KornKali) fertilizes were not available to use in the trials. The problems at the customs delayed planting time, and therefore some soil and foliar treatments were modified as shown in Table 18 (more soil Zn applications are included).

Soil Zn was applied as water solution by syringe. Ten leaf samples (ear leaf) were collected from each plot before Zn foliar application. The 0.5 % Zn fertilizer solution was applied with CO_2 pressurized device, at 200 L ha^{-1} rate that is equivalent to 1 kg ha^{-1} of zinc sulfate.

Plots were hand harvested and mechanically shelled when kernels reached 270 g kg^{-1} water content. The grain samples (for the treatments 1, 2, 3, 4, 6, 8, 10 and 11), leaf samples (for the treatments 1, 2 and 8) and the soil samples (0-30 cm) were sent to Sabanci University, for the corresponding analysis. At the same time, as parallel analysis, the soil samples (0-20 and 20-40 cm) were analyzed in the Agronomic Institute Laboratory.

Table 18: Treatments of Brazilian maize trials performed in 2009.

[redacted]

RESULTS AND DISCUSSION:

GRAIN YIELDS:

Grain yields were very low at Assis and Itararé because of the delayed date of sowing (due to the custom problems for some fertilizers) and climate constraints (e.g., drought in Assis (during silking) and frost in Itararé (kernel milk stage). Moreover, plants had the leaf disease turcicum leaf blight (*Exserohilum turcicum*) in Itararé during the maturation stage.

The treatments tested did not influence yield (Table 19). The soil zinc level was low or medium as shown in Table 20, but we did not observe significant differences in grain yield among the treatments. In addition, the time for the second Zn application (e.g., after silking of plants) is not practical to be used by farms. Generally, farmers spray maize crops with fungicides until pre-silking. We should change the Zn foliar application to V8 (first) and pre-silking plant (second) to link this work with farmers' requirements and fertilizer market.
The maize variety Al Bandeirante could be changed to a single-cross hybrid. Although the variety is used by small farms, its plants are not uniform and its grain production potential is low, which makes it difficult to detect productivity differences.

Table 19: Effect of Zn treatments on grain yield of maize in Itararé and Assis, Brazil.

[redacted]

Table 20: Soil fertility analysis results.

[redacted]

* Range of soil available zinc levels (DTPA-extractable): low = 0-0.5, medium = 0.6-1.2 e high = >1.2

GRAIN NUTRIENT CONCENTRATIONS:

The grain concentrations of Zn, Fe and P are presented in Table 21. At the Assis location with low grain yield, grain Zn concentrations (and also partly P and Fe concentrations) were slightly higher than those from the Itarare location, possibly due to lower grain yield and thus associated dilution of the nutrients in the Itarare location. At both locations, soil applications of Zn fertilizers had very little effect on grain Zn concentration, while foliar Zn fertilizers were more effective in increasing grain Zn concentration (Table 21). However, increases in grain Zn concentration by foliar Zn fertilizers were not sufficiently high as found with wheat

.

Table 21: Grain concentrations of Zn, Fe and P of plants grown in Assis and Itararé

Treatment	Assis Zn	Assis Fe	Assis P	Itararé Zn	Itararé Fe	Itararé P
	(mg kg^{-1})	(mg kg^{-1})	(%)	(mg kg^{-1})	(mg kg^{-1})	(%)
Standard	24	22	0.28	18	20	0.26
Standard + soil $ZnSO_4$	27	21	0.29	19	21	0.26
Standard + foliar $ZnSO_4$	27	22	0.28	22	21	0.26
Standard + soil ZnSO4 + foliar $ZnSO_4$	29	22	0.30	22	21	0.25
Standard + foliar $ZnSO_4$	28	21	0.27	22	20	0.25
Standard + foliar $ZnSO_4$	27	22	0.28	22	22	0.26
Standard without Ca Mg	26	22	0.28	19	19	0.26
Mosaic-soil	26	21	0.29	18	20	0.25
Standard + soil Zn/2	25	22	0.28	18	20	0.26
Standard + soil Zn/2 + foliar $ZnSO_4$	28	22	0.28	23	20	0.26
Mosaic-soil + foliar ZnSO4	27	21	0.27	22	20	0.26
Standard without Ca Mg + foliar $ZnSO_4$	28	22	0.28	23	22	0.26
MEAN	26.9	21.6	0.28	20.7	20.5	0.26
CV (%)	6.8	9.5	8.7	6.1	7.8	5.2
F TEST	<.001 (***)	ns	ns	<.001 (***)	ns	ns
LSD (0.05)	2.13	2.24	0.03	1.31	1.66	0.01

*Indicates significance at *P* 0.05; ** Indicates significance at *P* 0.01 and ns Indicates non significant. Means followed by the same letters, in columns, do not differ by Tukey's test (0.05).

WHEAT EXPERIMENTS:

EXPERIMENTAL ACTIVITIES:

In these trials, the effect of foliar Zn fertilization on grain Zn concentrations has been tested with and without fungicide applications. Two experiments were conducted in Sao Paulo State, both in the Capão Bonito´s Experimental Station (24º00'21" S and 48º20'58" W, 702 m elevation). The climate of the region according to the Koppen's classification is Cwf: subtropical with a rainy summer and wet winter.

The trials were planted in May of 2009 (Table 22). The genotype used was IAC 375, which represents the farmers' wheat cultivar. Experimental plots had nine 17 cm rows, 1.5 m wide and 8.0 m long. The initial population was of 70 plants m^2. Weed control was done by using 5 g ha^{-1} herbicide Ally (Metsulfuron). Basal NPK fertilizers were applied at the planting and 30 days after plant emergence, ammonium sulfate fertilizer was side dressed at the rate of 100 kg ha^{-1} (20 kg N ha^{-1}).

The treatments, performed around two-three months after the plants' emergence, were:

1. Standard or check;
2. Foliar application of 0.5 % ZnSO4.7H20 (2 times);
3. Foliar application of Opera Fungicide at 0.6 L ha^{-1} (2 times);
4. Foliar application of 0.5 % ZnSO4.7H20 and 0.6 L ha^{-1} Opera Fungicide (2 times).

Soil and leaf samples were collected from each trial before the foliar Zn application. The fungicide and 0.5 % Zn fertilizer solutions were applied with a CO_2 pressurized device, at 200 L ha^{-1} .The active ingredients of fungicide Opera are Epoxiconazol + Piraclostrobina (50 + 133 g L^{-1}), made by Basf Company. Only in the first wheat trial, all plots were sprayed with

0.6 L ha^{-1} of Órius fungicide (tebuconazole 250EC), two weeks before the start of the treatments.

Table 22: Dates of mainly activities at Capão Bonito wheat trials, São Paulo State, Brazil.

[redacted]

RESULTS AND DISCUSSION:

GRAIN YIELDS:

The average yield of the trials were lower (Table 23) than the yield average of the previous years. This might be related to the high rain precipitation during the plant maturation which possibly stimulated foliar and ear diseases. Therefore, the fungicide treatments significantly improved grain yield in both locations (increases in yield were 61 % and 72 % in the Trial 1 and 2, respectively) (Table 23). The analysis results of soil and leaf samples, collected from each trial before the foliar Zn application, are not ready yet. Due to differential level of soil fertility, yield capacity of the plants was lower both trials.

Foliar Zn application did not affect yield, but distinctly increased the grain Zn concentration. It is important to mention that the possible symptoms due to fungicide or Zn sprays were not observed on wheat leaves after application of fungicides and/or Zn. These trials will be (most probably) repeated next year to re-check the effects of the combined application of fungicide and Zn on grain Zn concentration.

Table 23: Treatments effects on wheat yield and grain Zn concentration at Capão Bonito trials.

[redacted]