INITIATIVE ON
Excellence in Agronomy

Agronomic Biofortification:

Uncovering the Evidence

A seminar organized by the Excellence in Agronomy Agronomic Initiative

Job Kihara Maguta, Gudeta W Sileshi, Peter Omondi Bolo, Dominic Mwanzia Mutambu, Andrew Musili Sila

The Global Issue of "Hidden Hunger"

~ 3 BILLION

People worldwide suffer from “hidden hunger” caused by micronutrient deficiencies, especially zinc (Zn) and iron (Fe).

- Insufficient dietary intake is one of the leading causes of Zn and Fe deficiencies
- Management of NPK has been main focus in fertility work, with decades of mining micronutrients
- Yield increases due to micronutrients fertilization are starting to shift fertilizer formulations.
- Evidence on improvements of produce quality, e.g. density of Zn and Fe lacking

INITIATIVE ON
Excellence in Agronomy

Generating Evidences for Agronomic Biofortification

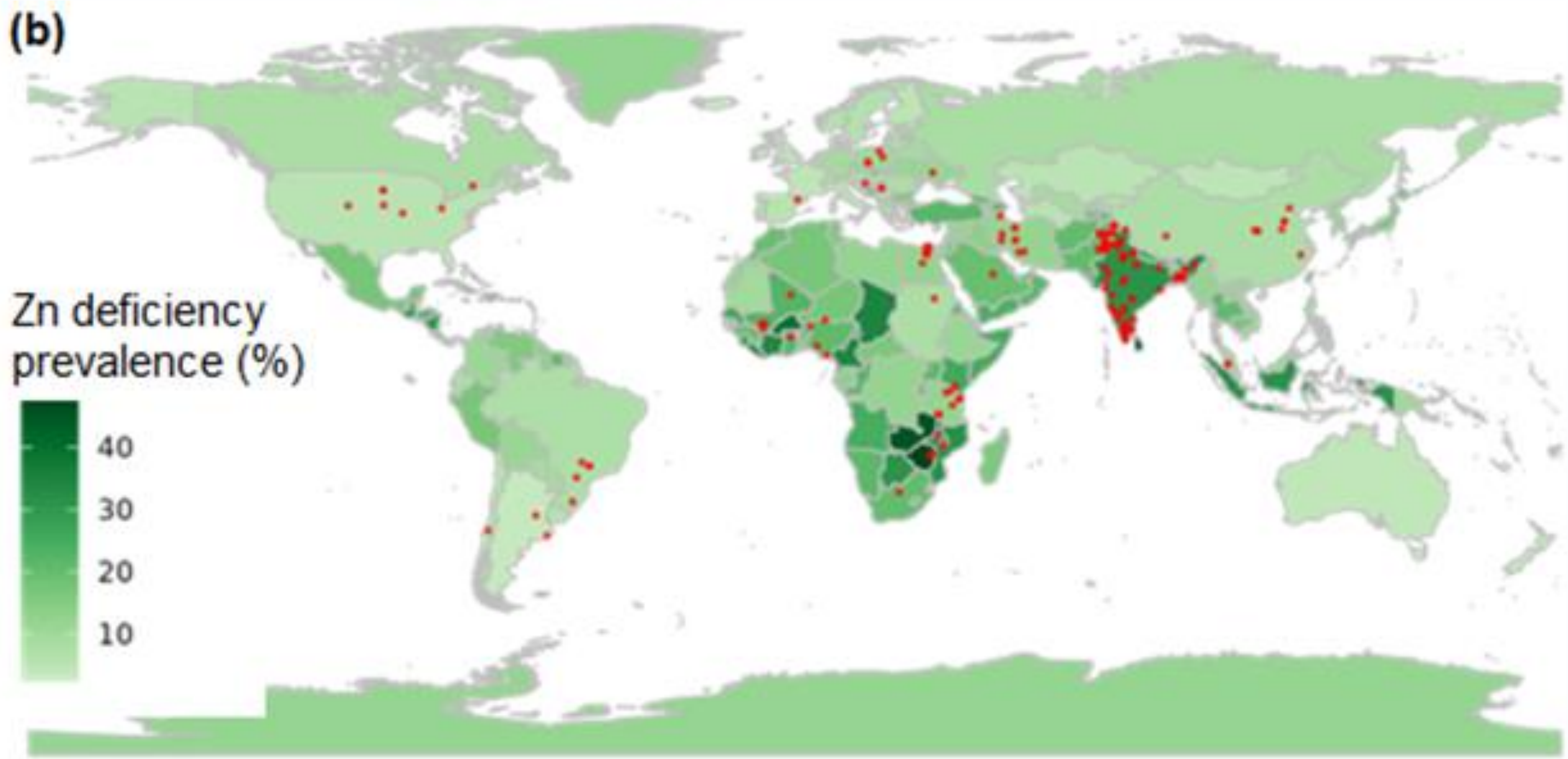
Specifying The Extent To Which And The Conditions Under Which This Is Achievable

Eia Strategic R&D on Agronomic Biofortification

- What are the appropriate on-station and on-farm trial designs for detecting changes in the KPIs of produce quality for different staple crops? *[in order to identify and use robust on-station and on-farm trial designs]*
- What measurements (including rapid IR techniques), modeling tools and methods are appropriate to monitor nutritional key performance indicators (KPIs) for different crops? *[to identify and use suitable methods and models for produce quality assessment]*
- How do combinations of GENE (including biofortified staple crops), ENVIRONMENT (soil, climate), and MANAGEMENT (crop and land management practices) influence crop produce quality? *[to generate evidence and solutions to improve produce quality to secure nutritional security outcomes]*
- Where are the priority micro-nutrient deficient/responsive geographies for spatial targeting of interventions to achieve large-scale agronomic gains? *[targeting impact to scale]*

EXCELLENCE IN AGRONOMY
ADAPT INTENSIFY GROW
AfricaRice
Bioversity International
CIAT
CIMMYT
CIP
World Agroforestry Centre
ICARDA
ICRISAT
IFPRI
IITA
IRRI
IWMI

Building a Global Database for Generating Evidences



- Agronomic trials data
- Systematic literature reviews and data digitization

Agronomic Biofortification:

Global Meta-Analyses on Maize

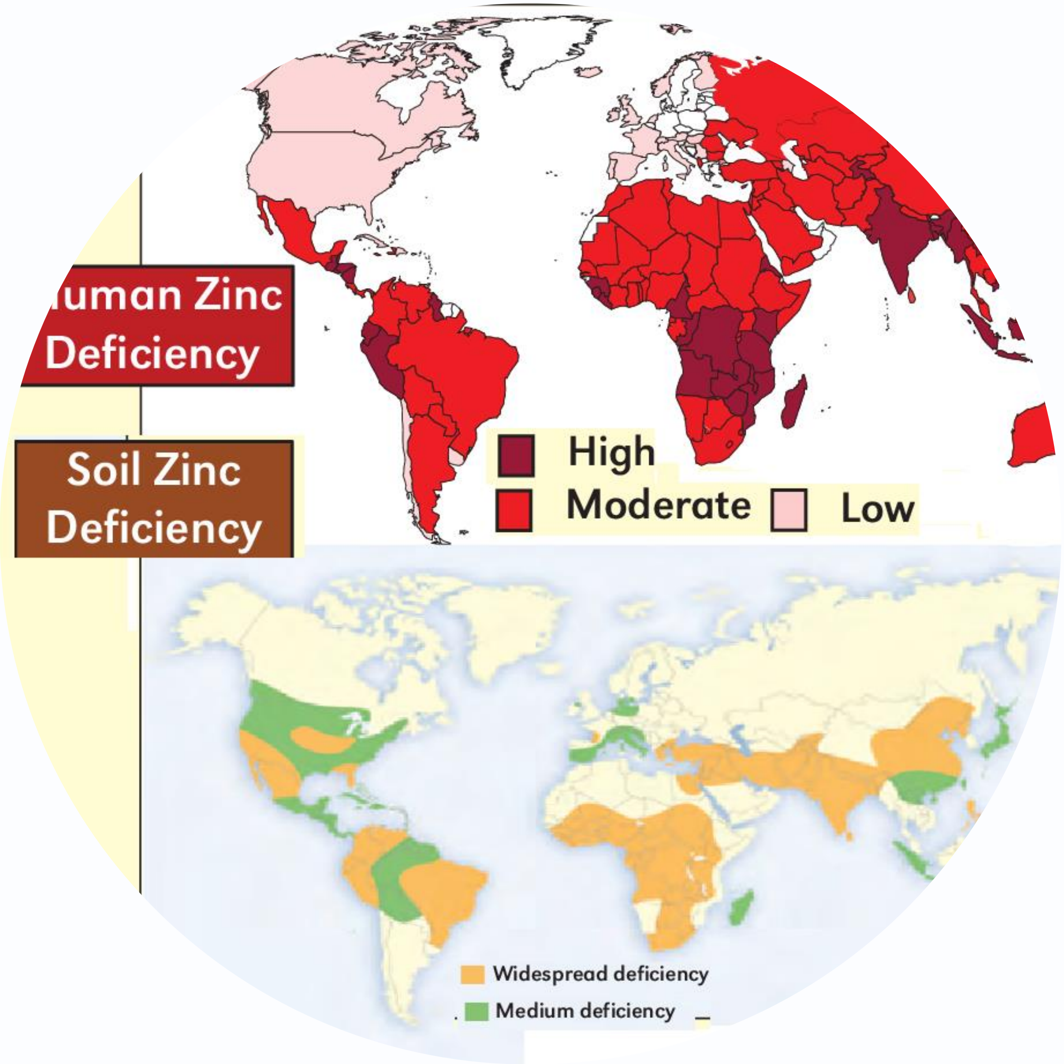
INITIATIVE ON
Excellence in Agronomy

CGIAR

EXCELLENCE IN AGRONOMY
ADAPT INTENSIFY GROW

Maize Grain Zinc and Iron Concentrations

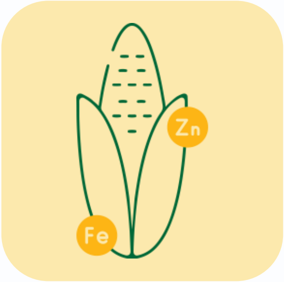
as influenced by agronomic management and biophysical factors



1a. Background and justification

- Zinc (Zn) and iron (Fe) deficiencies affect ~3 billion people globally
- Insufficient dietary intake is one of the leading causes of Zn and Fe deficiencies
- Zn and Fe deficiencies are high in populations consuming staple cereals
- Regions with Zn-deficient soils are characterized by Zn deficiency in humans
- Agronomic practices, soil and climate often determine availability of Zn and Fe
- Information is lacking on the distributions of Zn and Fe in maize grain
- Information is also lacking on how effect sizes vary with agronomic and biophysical factors

1b. Objectives of The Meta-Analysis



To establish the distribution of Zn and Fe concentrations in maize grain at the global scale and the probability of attaining nutrient concentration targets

To assess the contribution of different agronomic practices in increasing the concentrations of Zn and Fe in maize grain

To identify key biophysical factors and metrics to guide agronomic biofortification

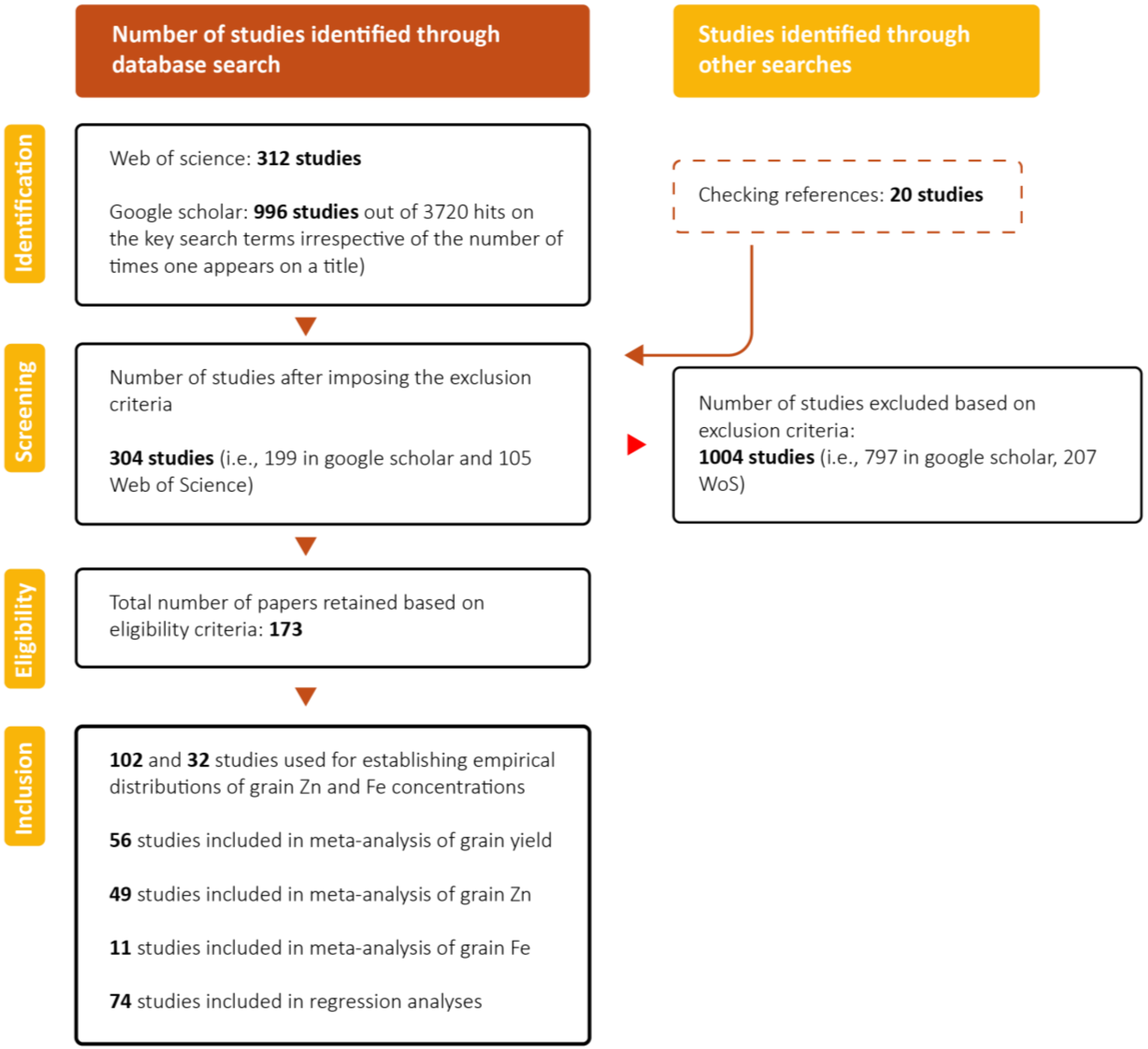
1a. Background and justification

1. Benchmark concentrations of Zn (38 mg kg^{-1}) and Fe (60 mg kg−1) in maize grain are attainable with agronomic innovations;
2. There are significant differences in grain concentrations of Zn and Fe due to different agronomic practices;
3. Concentrations of Zn and Fe are influenced by soil biophysical factors

2. Method

We followed recommended steps for the meta-analysis

We used the response ration (treatment/NPK) as our effect size



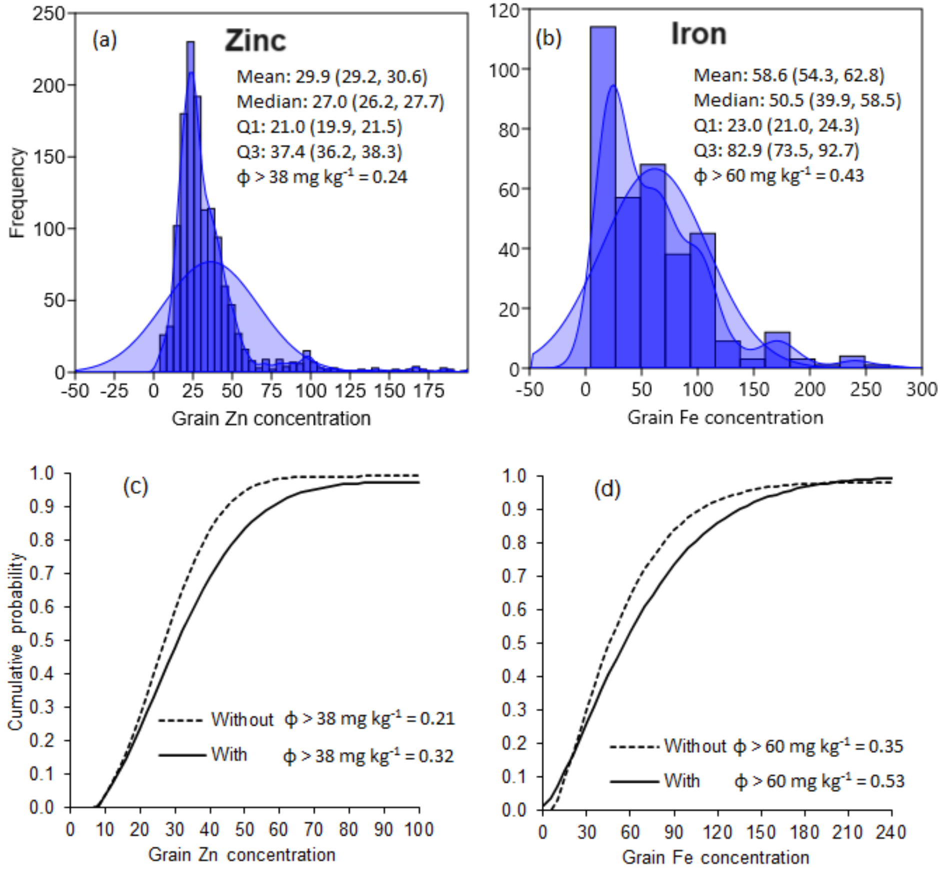
Number Of Studies and Total Number of Observations Available for Meta-analysis

Variable	No. of Studies	Countries	Observations	After removing outliers					
				Mean	Median	Q1	Q3	CV (%)*	Outliers
Zn (mg kg $^{-1}$)	102	24	1332	29.9	27.0	21.0	37.4	43.3	86
Fe (mg kg $^{-1}$)	32	15	359	58.6	50.5	23.0	82.9	70.5	9
Proteins (%)	90	21	1349	9.2	9.2	8.0	10.3	27.9	8
Nitrogen (%)	38	14	443	1.7	1.6	1.4	1.8	32.9	32
Grain P (%)	37	10	485	0.48	0.34	0.26	0.48	126.8	20

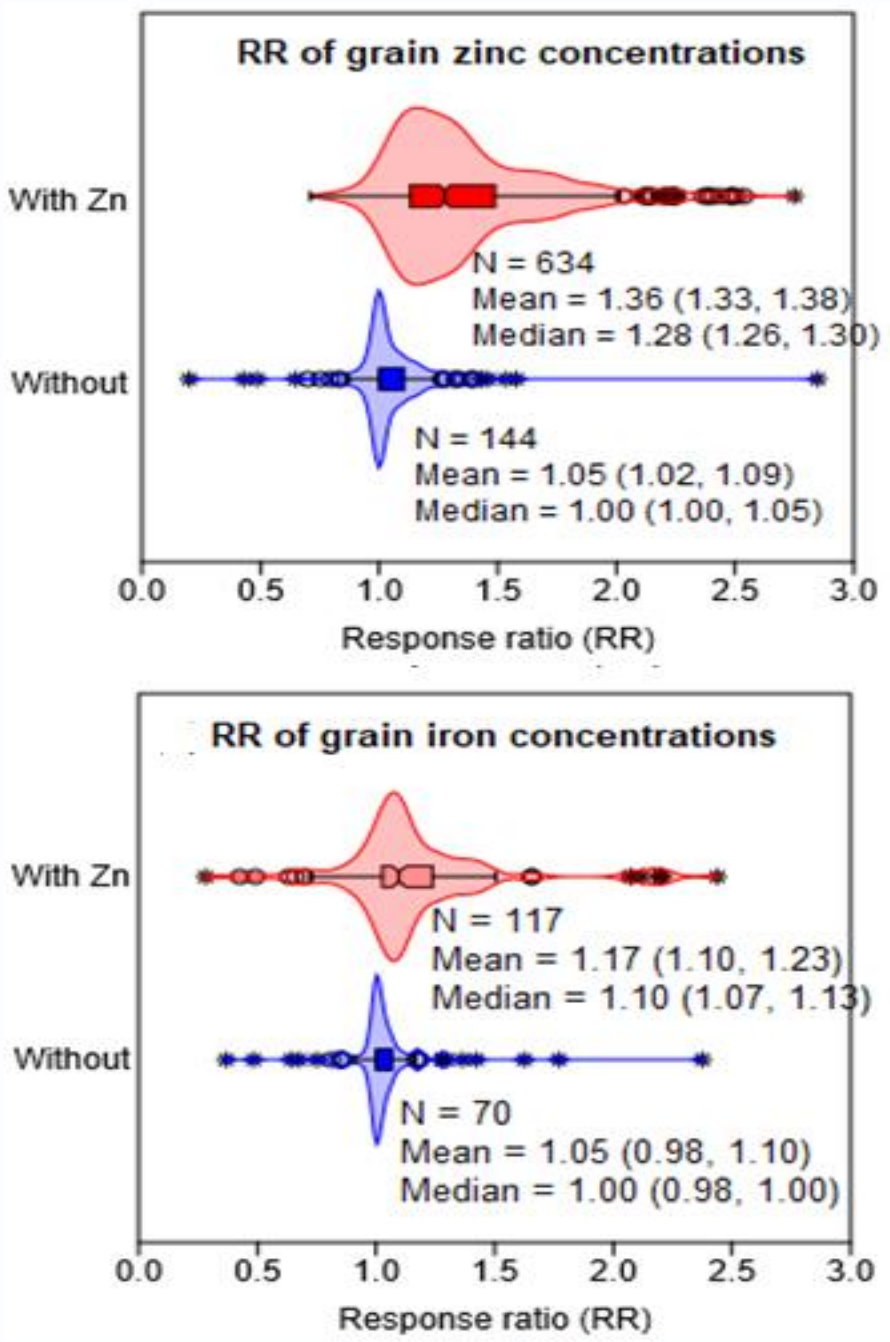
3. Synthesis

Distributions of Zn and Fe in maize grain

- The overall probability of grain Zn concentrations exceeding the benchmark of **38 mg kg^{-1}** was only 24%
- The probability of grain Fe concentrations exceeding the benchmark of **60 mg kg^{-1}** was 43%
- When Zn was applied ("With") to the soil, the probabilities were increased to 32% for Zn and 53% for Fe



EXCELLENCE IN AGRONOMY
ADAPT INTENSIFY GROW

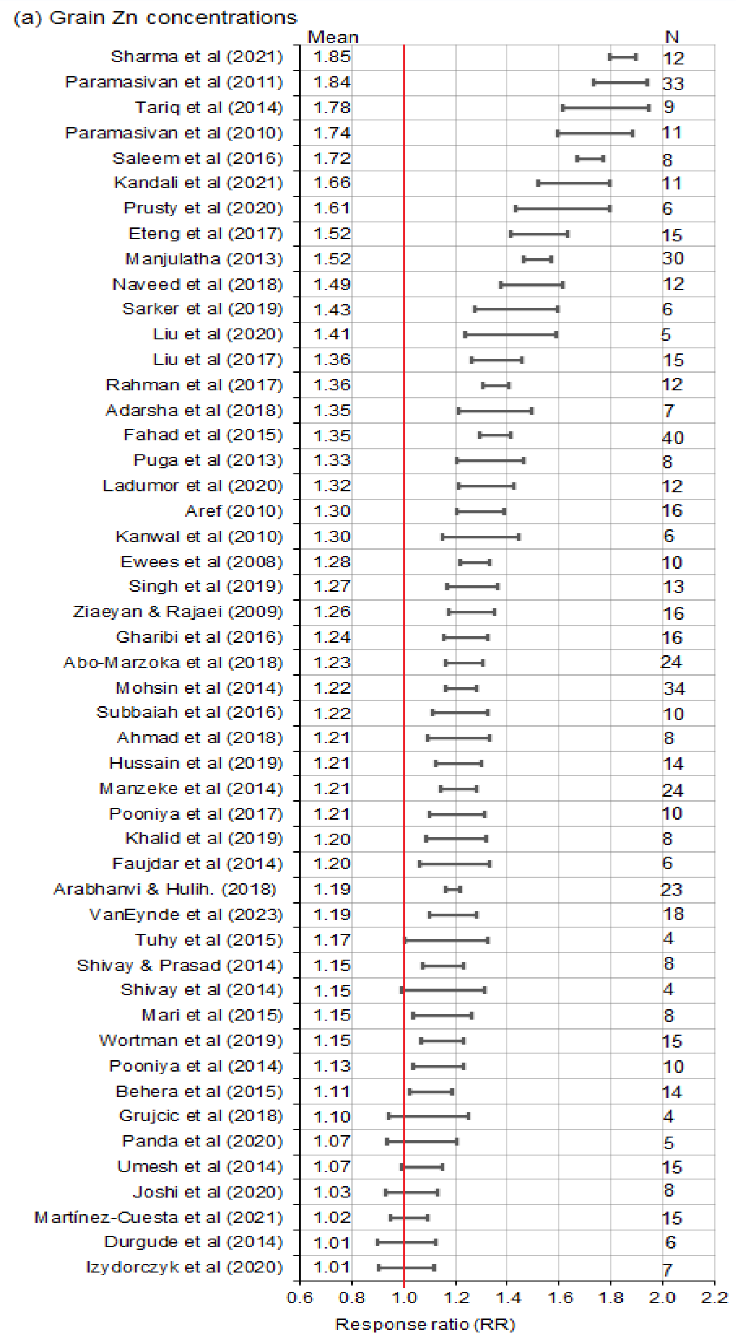


Overall effect of Zn application on grain Zn and Fe concentrations

- Overall, Zn application increased grain Zn concentrations by 28% over the NPK fertilizer
- It also increased grain Fe concentrations by 10%

Between-study variation in response to Zn application

<u>Grain yields</u> significantly increased with Zn application relative to the NPK control in 27 out of 56 studies

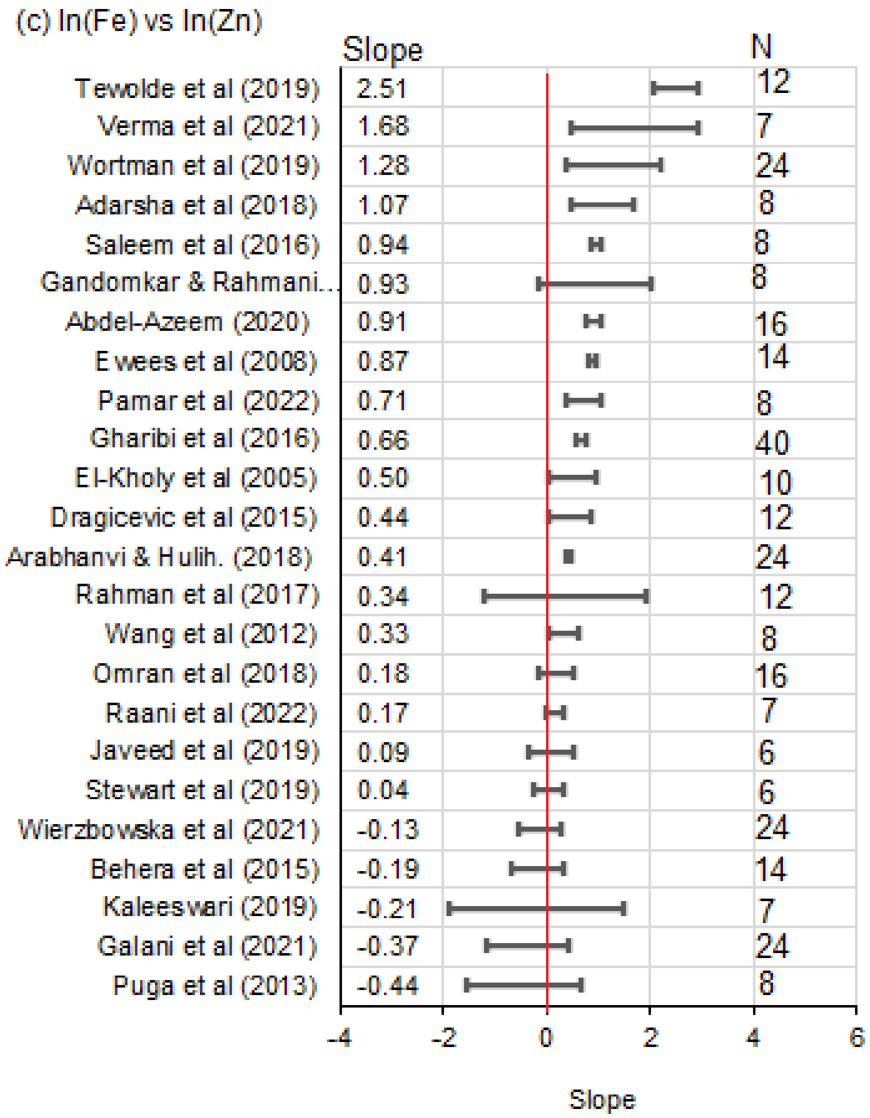


Between-study variation in response to Zn application

Grain Zn concentrations significantly increased with Zn application relative to the NPK control in 40 out of 49 studies.

Association between grain yield, Zn, Fe and protein concentrations

- **Grain yield vs grain Zn concentrations:**
  32 out of 61 studies had significantly positive slopes
- **Grain yield vs grain Fe concentrations:**
  6 out of 16 studies had significantly positive slopes
- **Grain yield vs grain protein concentrations:**
  6 out of 11 studies had significantly positive slopes
- **Grain protein vs grain Zn concentrations:**
  10 out of 18 studies had significantly positive slopes
- **Grain Zn vs Fe concentrations:**
  14 out of 24 studies had significantly positive slopes

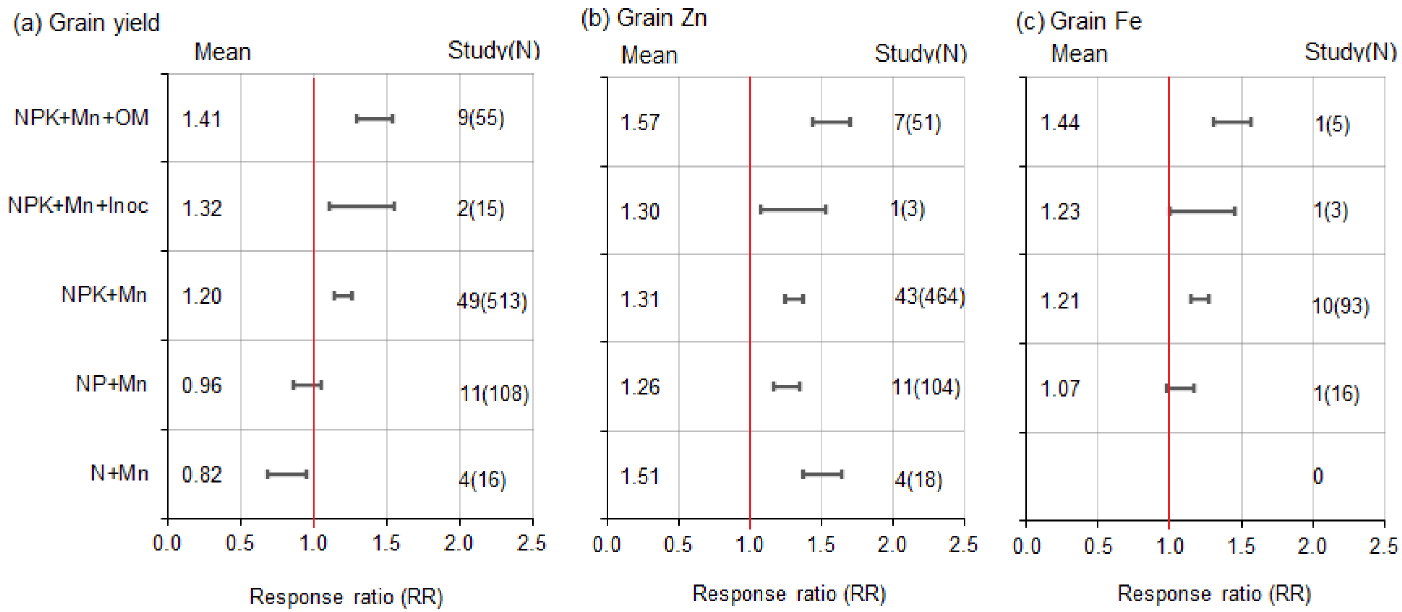


Take-away message:

Increases in grain yield, grain Zn, Fe and protein concentrations can be achieved concurrently

Treatment effects on grain Zn and Fe concentrations

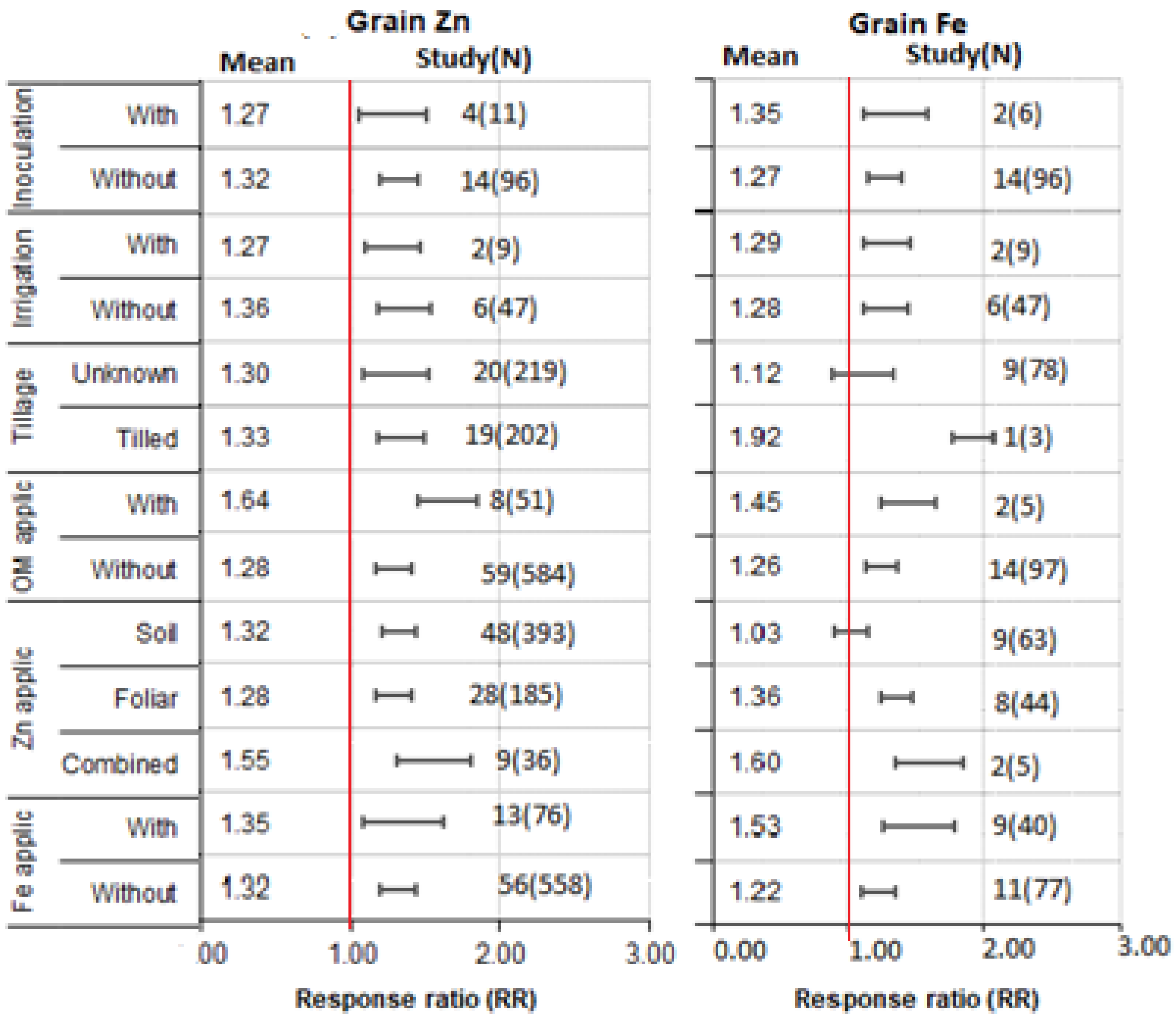
The combined application of NPK, micronutrient and organic inputs (NPK+Mn+OM) increased grain yield by 41%, grain Zn by 57% and Fe concentrations by 44% relative to the NPK control



Treatment effects on grain Zn and Fe concentrations

The combined application of NPK, micronutrient and organic inputs (NPK+Mn+OM) increased grain yield by 41%, grain Zn by 57% and Fe concentrations by 44% relative to the NPK control

Small sample sizes preclude definitive conclusions about inoculation and irrigation effects.

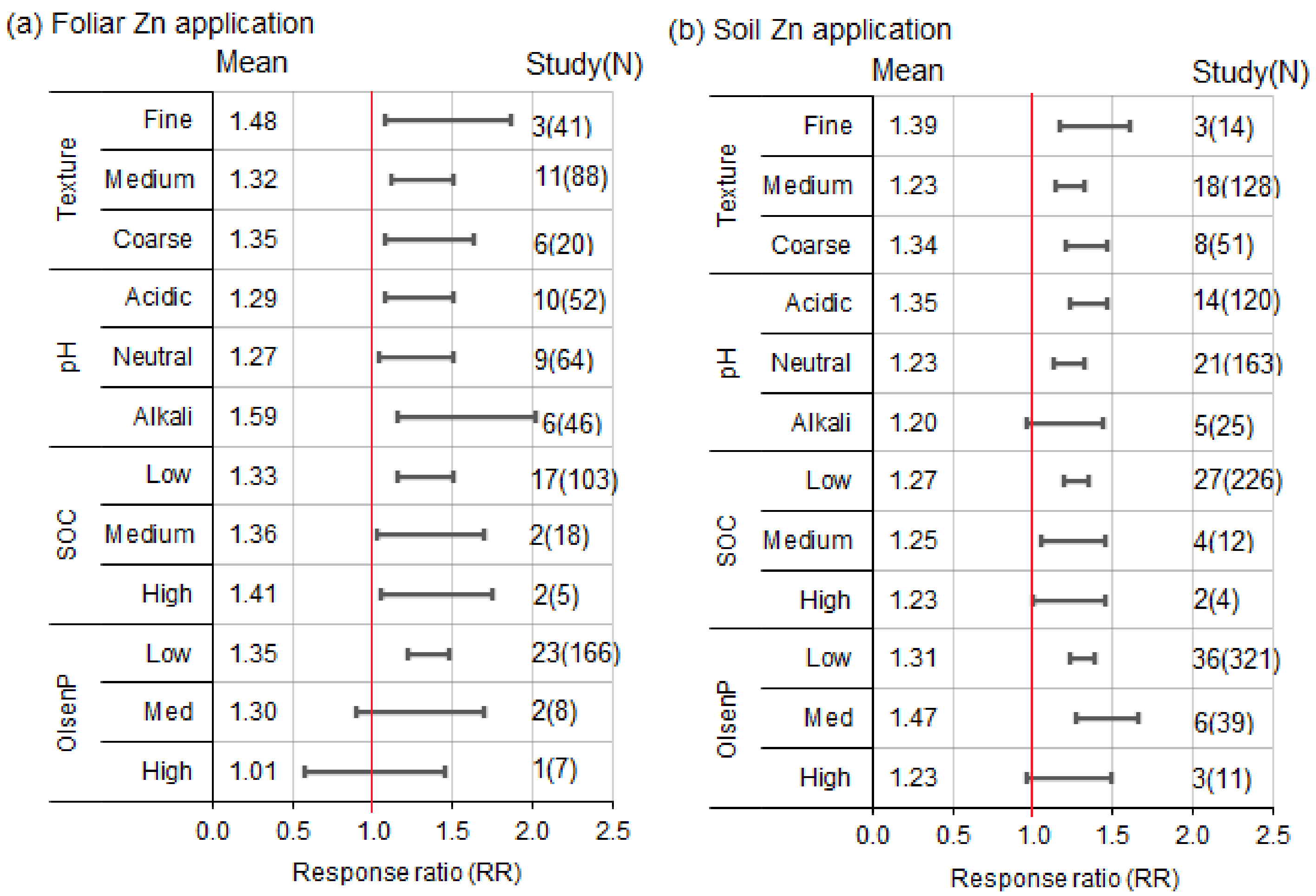


AfricaRice Bioversity International CIAT CIMMYT CIP World Agroforestry Centre ICARDA ICRISAT IFPRI IITA IRRI IWMI

Biophysical factors moderating responses

Effect of either foliar or soil application of Zn on grain Zn concentrations was higher on alkali soils and soils with low-medium Olsen P.

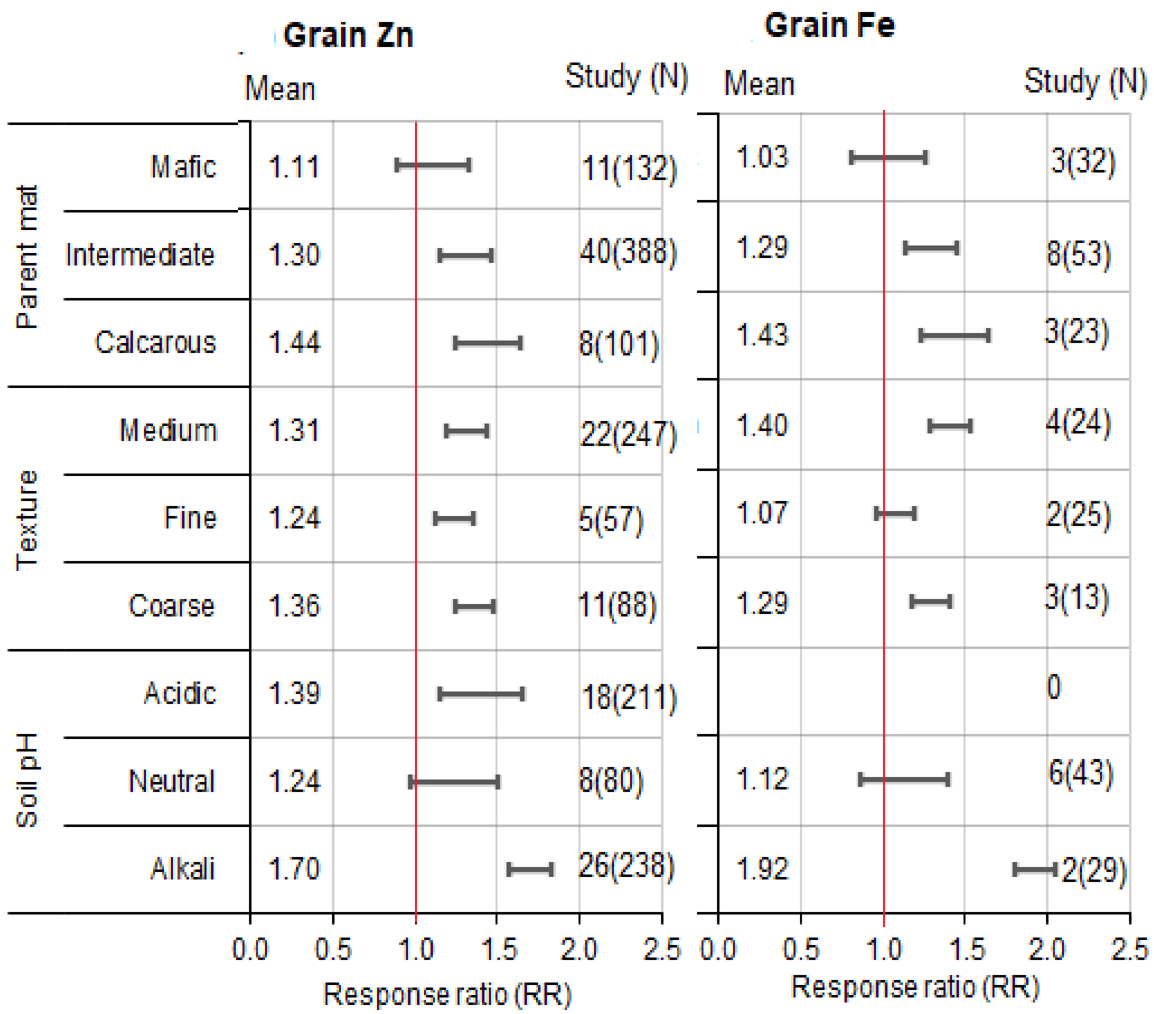
Small sample sizes preclude definitive conclusions.



Biophysical factors moderating responses

Overall effect of Zn application on grain Zn concentrations were higher on calcareous soils, medium to coarse-textured soils and alkali soils.

Small sample sizes preclude definitive conclusions about grain Fe concentrations.



Conclusions

- Through agronomic biofortification it is possible to increase Zn and Fe concentrations of maize grain by 32% and 31% relative to NPK fertilizer
- Zn concentrations of grain concomitantly increases with increases in grain yield and Fe, protein and P concentrations in the grain

INITIATIVE ON
Excellence in Agronomy

THANK YOU!