Keynote Speaker

Value of Balanced Nutrition Starts with the Seed

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INTRODUCTION

Balanced fertilization/mineral nutrition is a critical step in achieving improved crop production.

"Balanced nutrition" is often discussed in terms of **an adequate** and **a balanced** application of nutrients/fertilizers.

Very little attention is, however, paid to the importance of **seed nutrient reserves** when balanced nutrition of crop plants is discussed

Adequate level of nutrient reserves is required **for maximizing and ensuring success of balanced mineral nutrition** in improving crop production

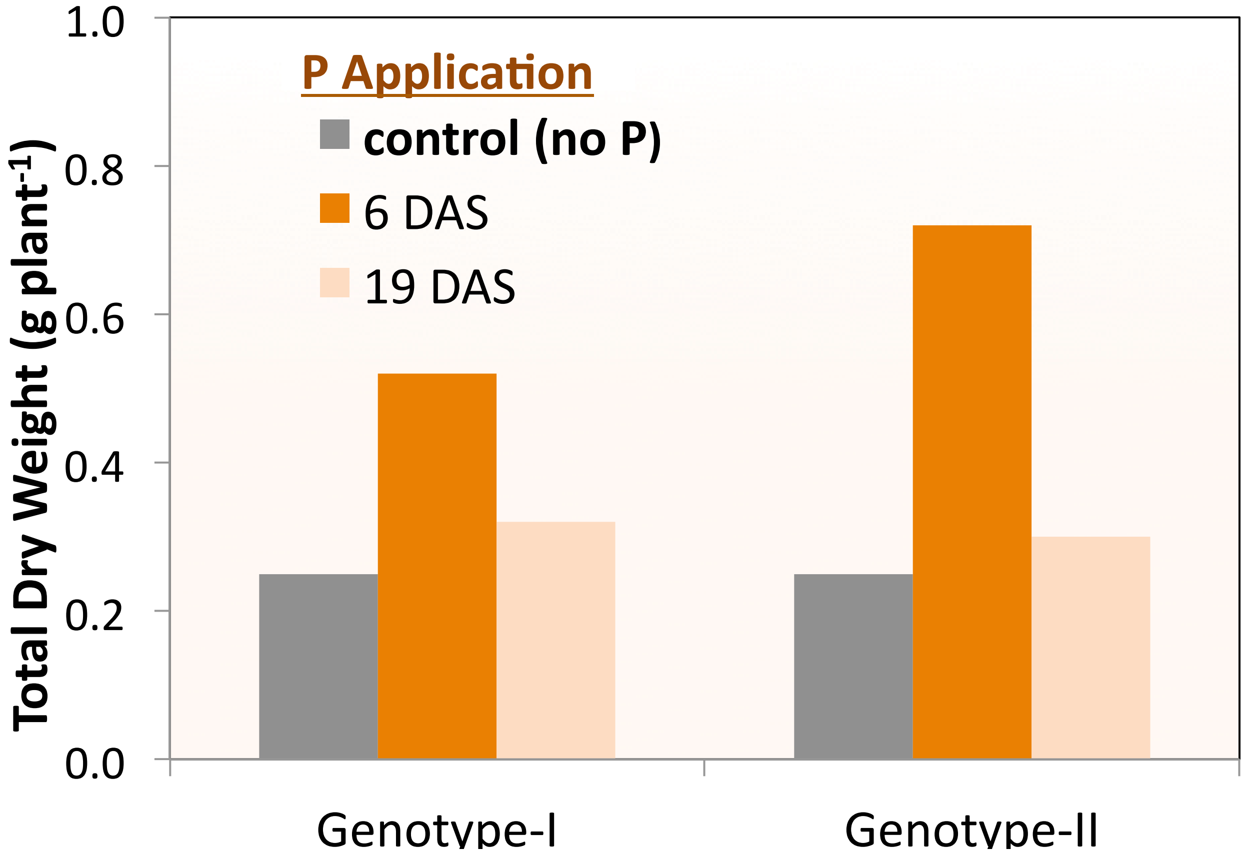
Seed reserves of nutrients represent a key factor affecting greatly seed germination, seedling emergence and uniformity of the emergence in the field and final yield of plants.

Well-known positive **impact of larger seeds on seedling vigor** and field establishment is often attributed to higher amount of seed reserve nutrients in seed.

Today, several examples will be shown to demonstrate importance of seed nutrients in achieving better seedling vigour and final yield

Very early season P supply is more critical in achievement better yields than the supply of P at later growth stages (Grant et al 2001, Can. J. Plant Sci. 81: 211-224) **that highlights importance of seed P reserves**

Changes in total dry weight of 2 pearl millet hybrid genotypes treated with soil P fertilization earlier (6 DAS) or later (19 DAS). Plants were harvested on days of 40 DAS

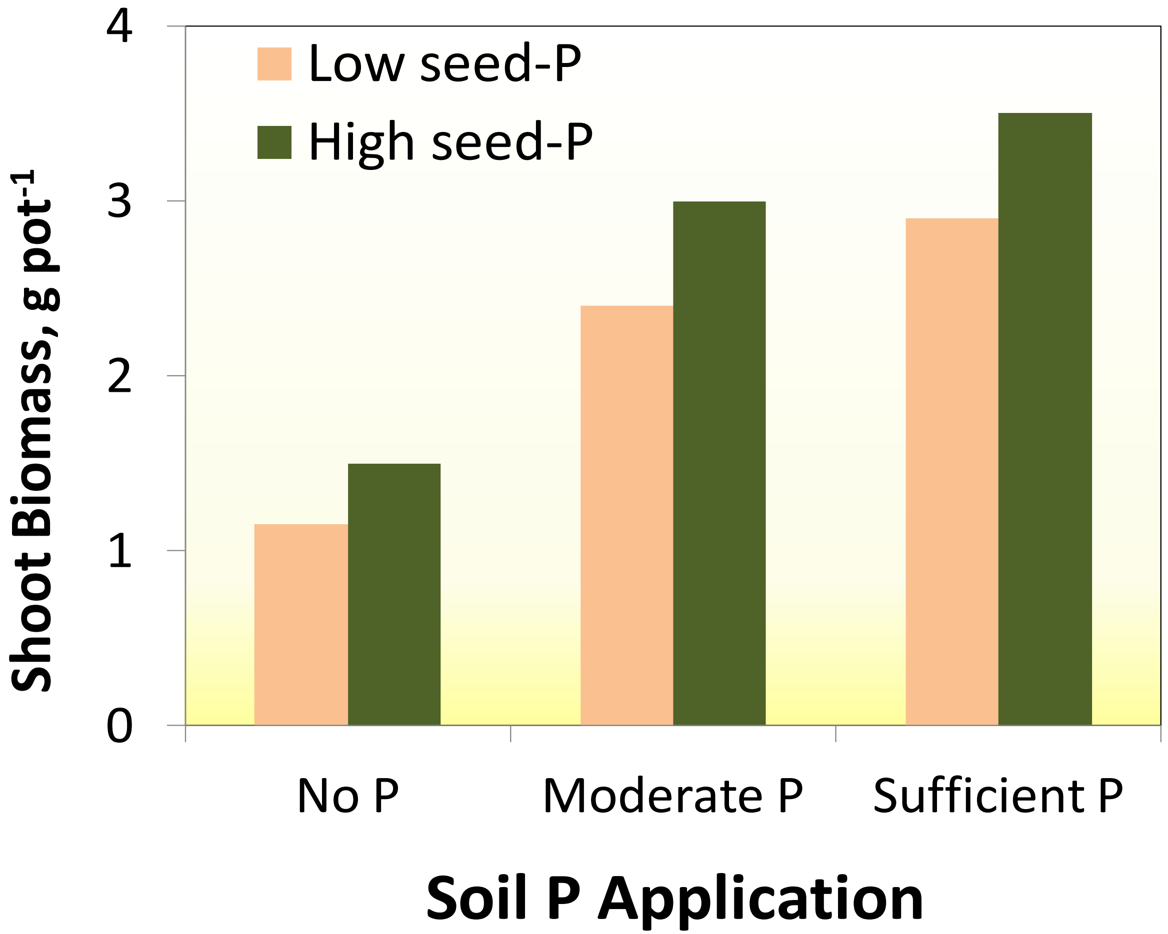


DAS: Days after sowing

Valluru et al. 2010, Soil Use Manag. 26: 36-43

Effect of **seed P reserves** and **soil P application** on shoot growth of wheat plants grown in a soil/sand mixture

(**Low-P seed**: 98 µg/seed; **High-P seed**: 213 µg/seed)



Even, at adequate P supply, use of seeds with high P is required in achieving better growth

Zhu and Smith, 2001,
Plant Soil, 231: 105-112

Effect of P-seed coating on growth and grain yield of oat plants grown under field in Finland

Parameter	control	P-coating
Veg. Growth		
g $plant^{-1}$	1.38	1.56
g m^2	623	683
Yield		
g $panicle^{-1}$	1.52	1.77
g m^2	687	774
No of grains m^2	16 200	18 100

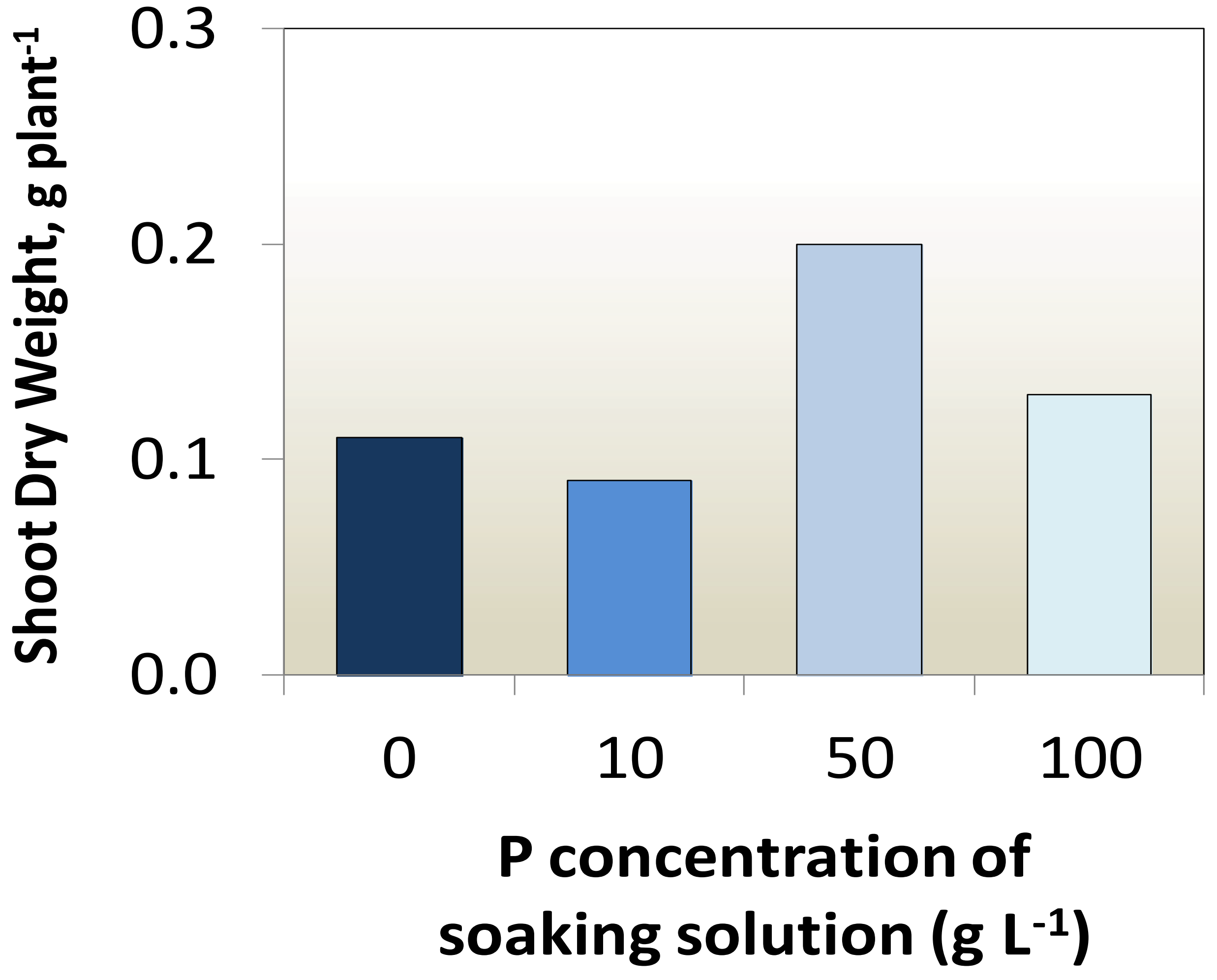
Peltonen-Sainio et al. 2006, Agron. J. 98:206-211

Effect of **seed coating** with increasing amount of P (from 0 to 77.5 mg P per gram seed) on shoot dry matter of pearl millet grown in a P-deficient and P-sufficient soil

Seed P-Treatment	Low P Soil	High P Soil
(mg P g^{-1} seed)	(g $plant^{-1}$)	
0	1.23	3.62
15.5	1.63	3.68
46.5	1.88	3.99
77.5	2.24	4.30

Karanam and Vadez, 2010,
Exp. Agric. 46: 457-469

Shoot dry weight of wheat plants derived from seeds which were **soaked** in a solution containing increasing amount of P



Ideal P-Solution:
50 g K-phosphate per liter (0.35 M K-Phosphate solution)

Sekiya and Yano, 2010, Plant Soil, 327: 347-354

Enrichment of legume seeds with phosphorus and molybdenum and yield

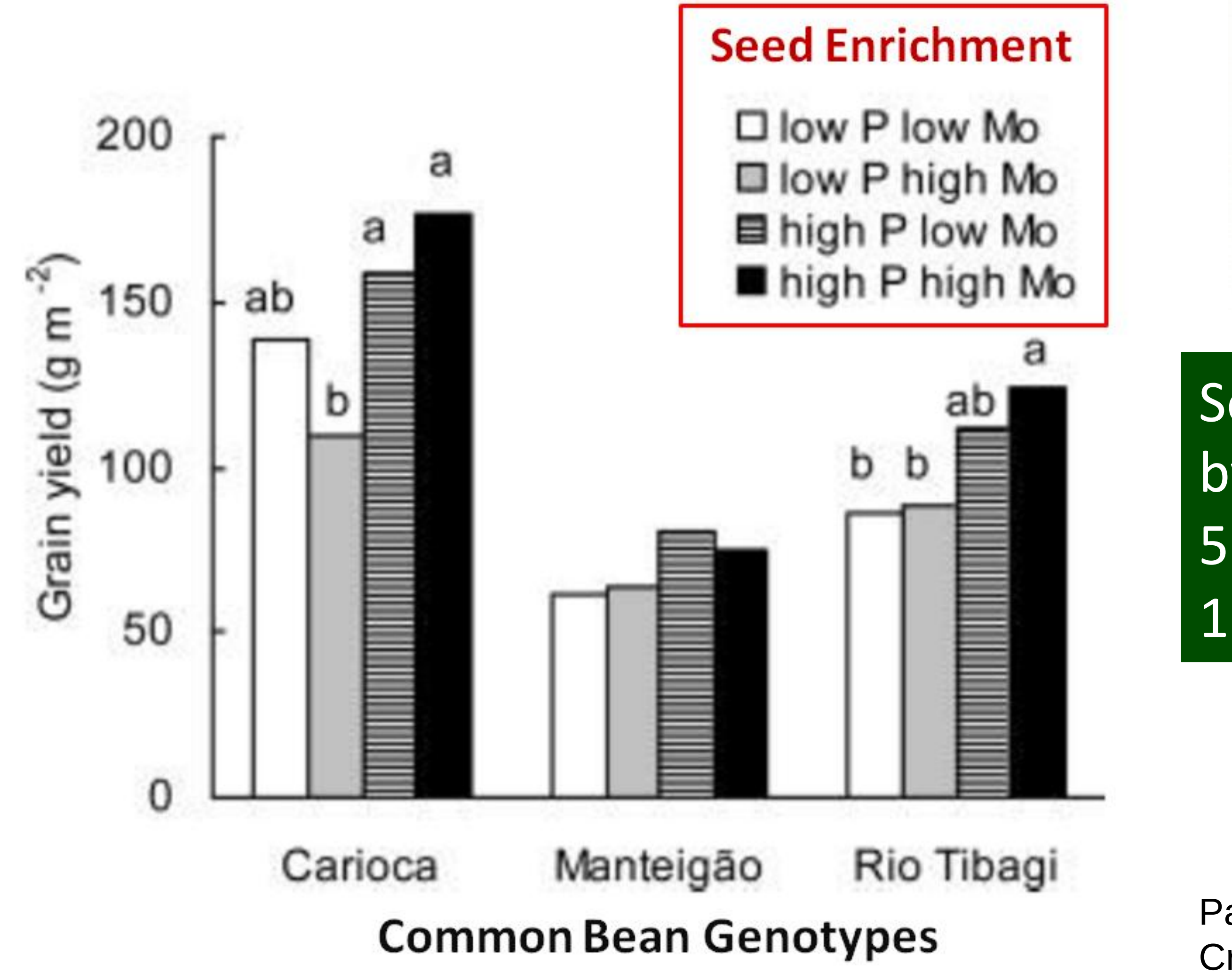
Legume plants depending on biological N_2 fixation for their N supply require more P and Mo than plants receiving fertilizer N, since the reduction of atmospheric N_2 by the nitrogenase system is a very energy-consuming process, and more Mo and P are needed for symbiotic N fixation than for general plant metabolism

(Israel, 1987, Plant Physiol, 84:835-840;

"Nodules act as strong sinks of Mo and P"

Grain yield of three common bean cultivars originating from seeds with different concentrations of P and Mo.

(Plants grown under field conditions in Brazil)



Seed enrichment by 2x sprays of 5 kg P ha^{-1} and 120 g Mo ha^{-1}

Pacheco et al. 2012, Field Crops Rs. 136: 97-106

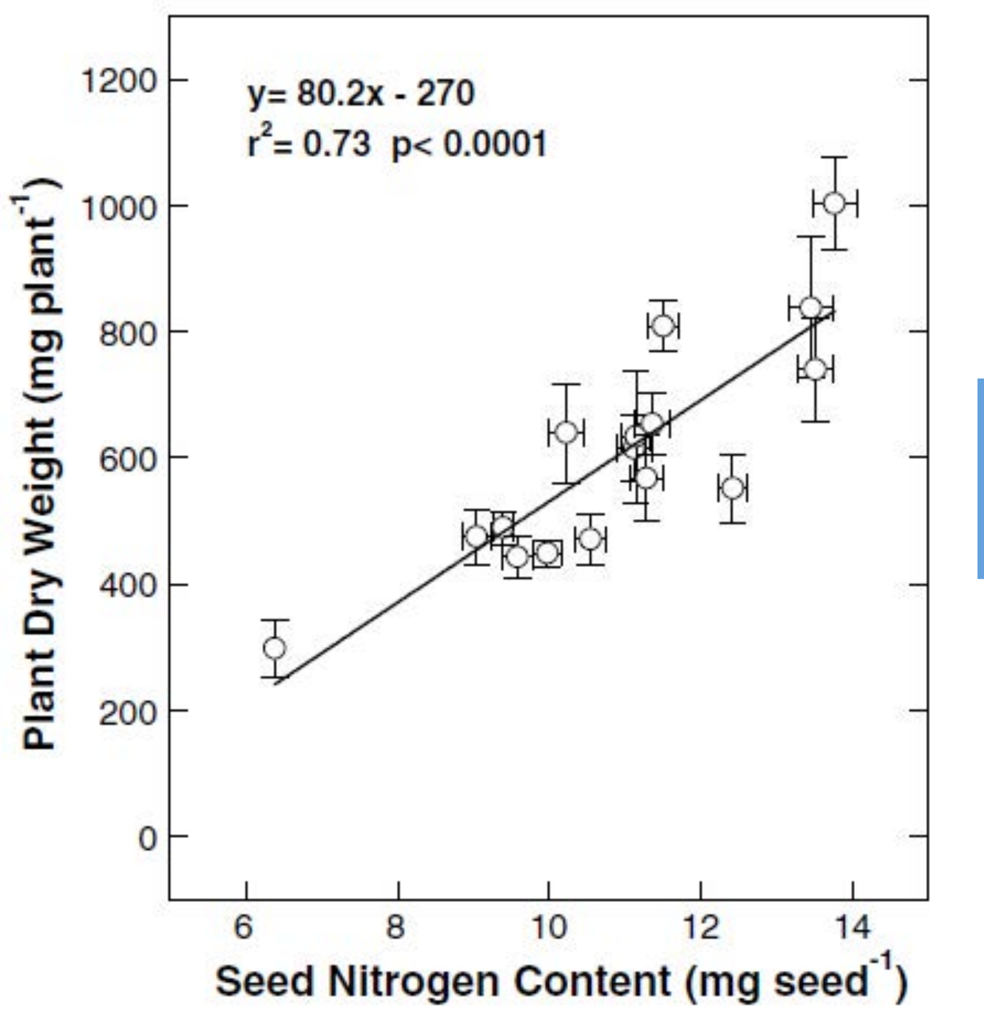
N Deficiency in Legume Seedlings and Seed N Reserves

Young legume plants also often suffer from obvious and hidden N deficiency when grown in acidic soils or in soils with low inorganic N and organic matter.

It is very common that legumes are rarely or at very low rates fertilized with N because N_2-fixation process provides sufficient N for high yields.

However, N_2-fixation system is fully established **4–5 weeks after germination**. During this period seed N reserves might be of great importance.

Relationship between seed N content and seedling dry weight of 16 soybean lines after 27 days of growth without an external N supply

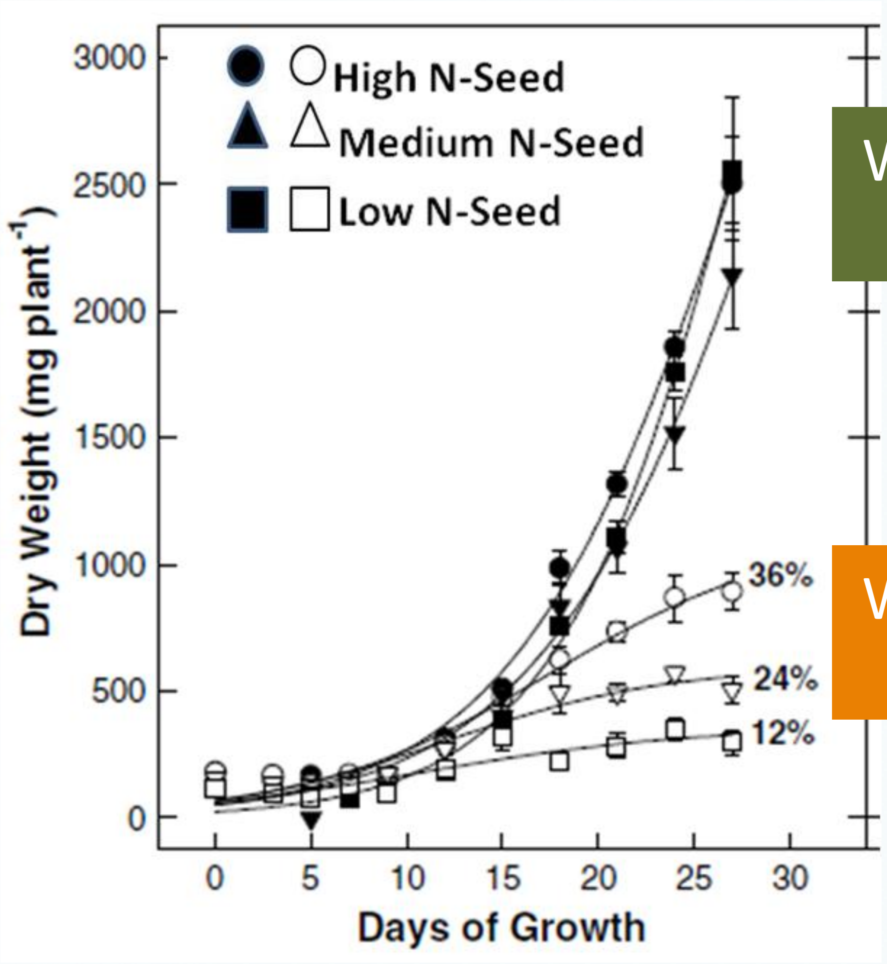


Seed N and Seedling Growth

Naegle et al 2005, Plant and Soil, 271: 329-340

Dry weight of isogenic soybean seedlings differing in seed N concentrations

Low N: 5.5 %;   Medium N: 6.3 %; High N: 7.4 %



When N supply is adequate

When N supply is inadequate

Naegle et al 2005, Plant and Soil, 271: 329-340

Micronutrients are of particular importance for seed vitality, seed germination and better seedling vigour

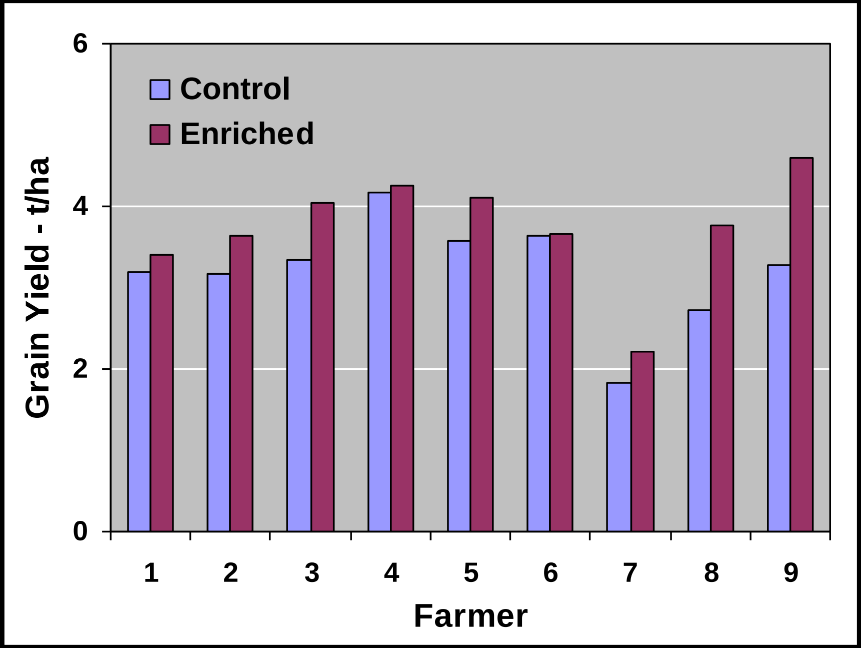
Impact of Micronutrient Dense Rice Seed in Bangladesh

Research Station

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

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

Farmer Fields



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

Effect of Micronutrient Enrichment of Wheat on Early Growth

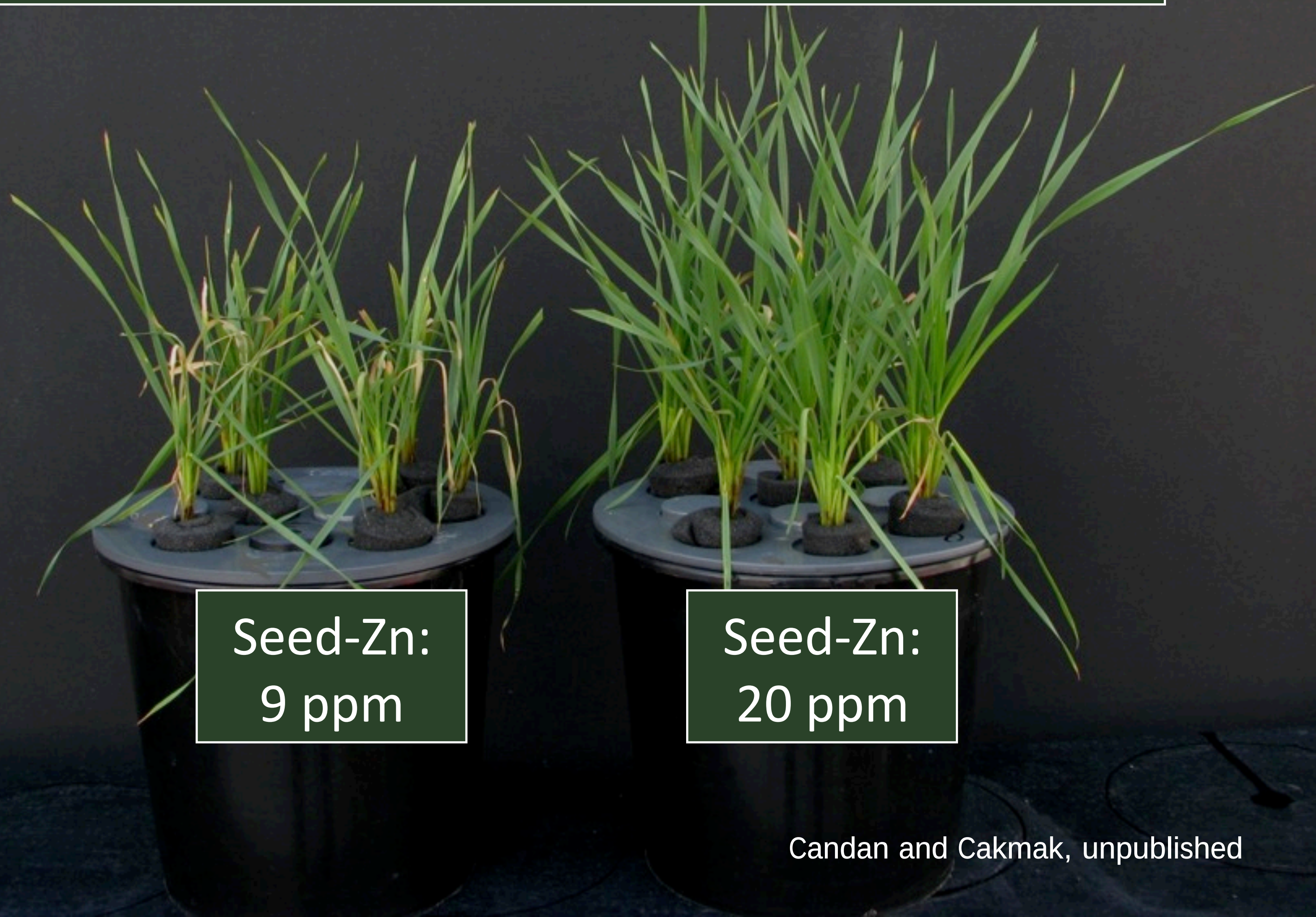
Enriched Seeds | Control/Farmer Seeds | Enriched Seeds | Control/Farmer Seeds

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

Newly developed radicles (roots) and coleoptile during seed germination contain up to 200 ppm Zn (Ozturk et al. 2006, Physiol. Plant.) which indicates particular roles of Zn during early seed germination and seedling development.

High seed Zn in seeds acts as a "**starter Zn fertilizer**"

Role of Seed Zn on Growth of Wheat Plants in a Growth Medium with low Zn supply

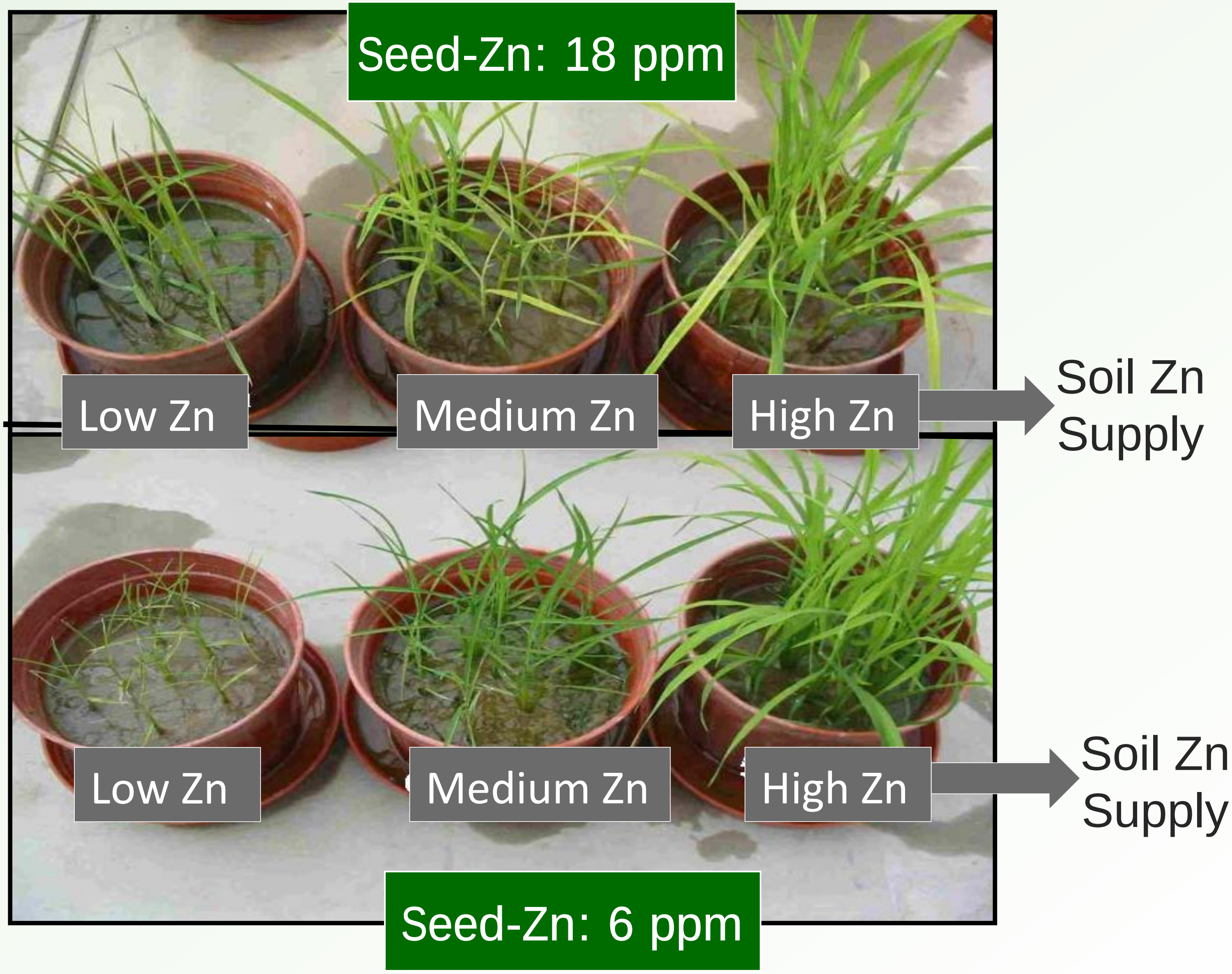


Candan and Cakmak, unpublished

Rice Cultivars Growing in a Zn-Deficient Soil

Genotype-A

Genotype-B

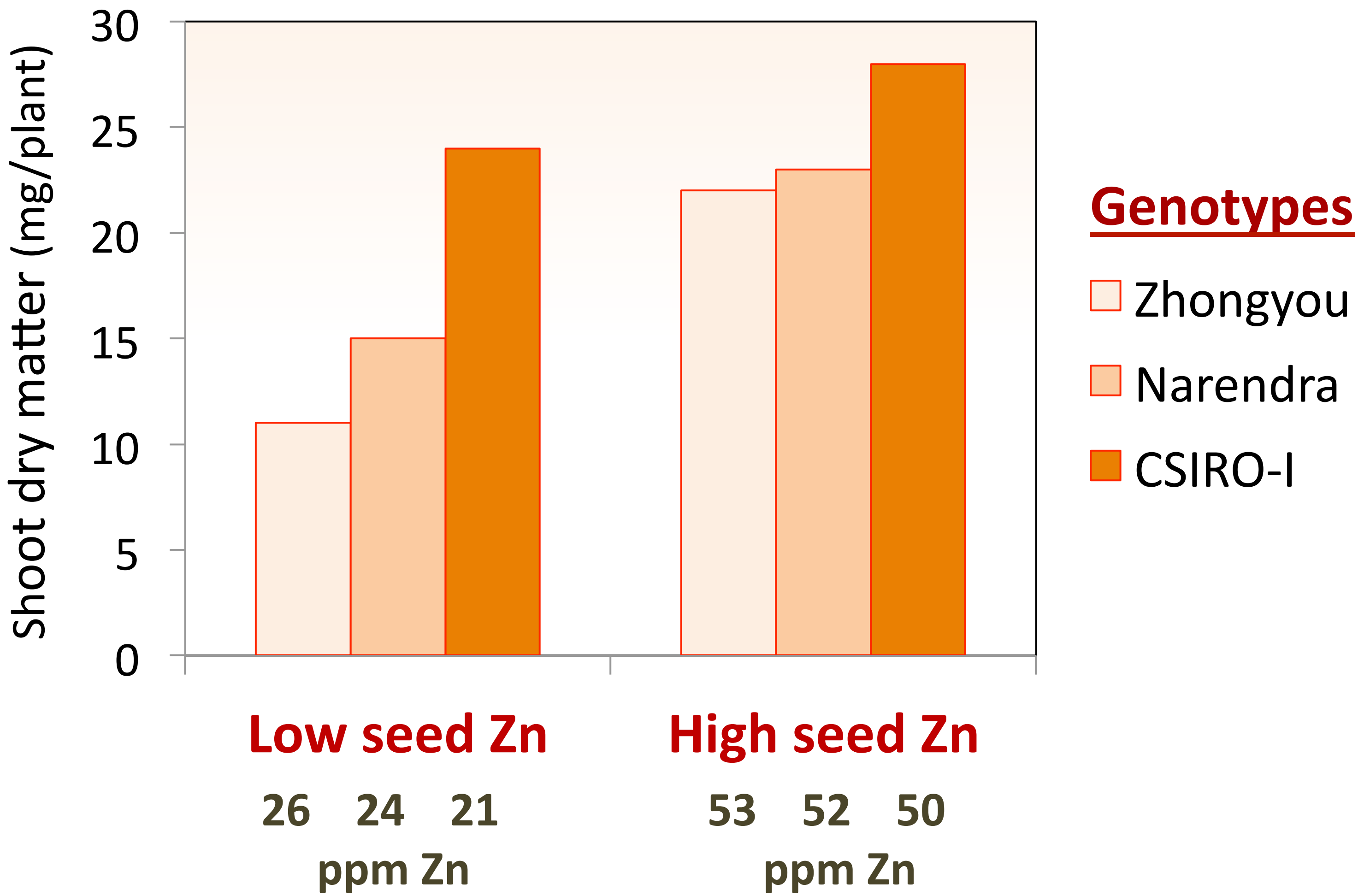


(Unpublished results)

Sowing rice seeds treated with Zn upto 5.7 g Zn per kg seed also improved germination and resulted in better root length and shoot growth in Kansas State (Slaton et al. 2001, Agron. J. 93: 152-157).

Effect of seed Zn concentration on shoot dry matter production of canola genotypes.

(Zhongyou: Zn-Inefficient; CSIRO: Zn-Efficient Genotypes)



Singh and Graham,1997,
Plant and Soil, 192: 191-197

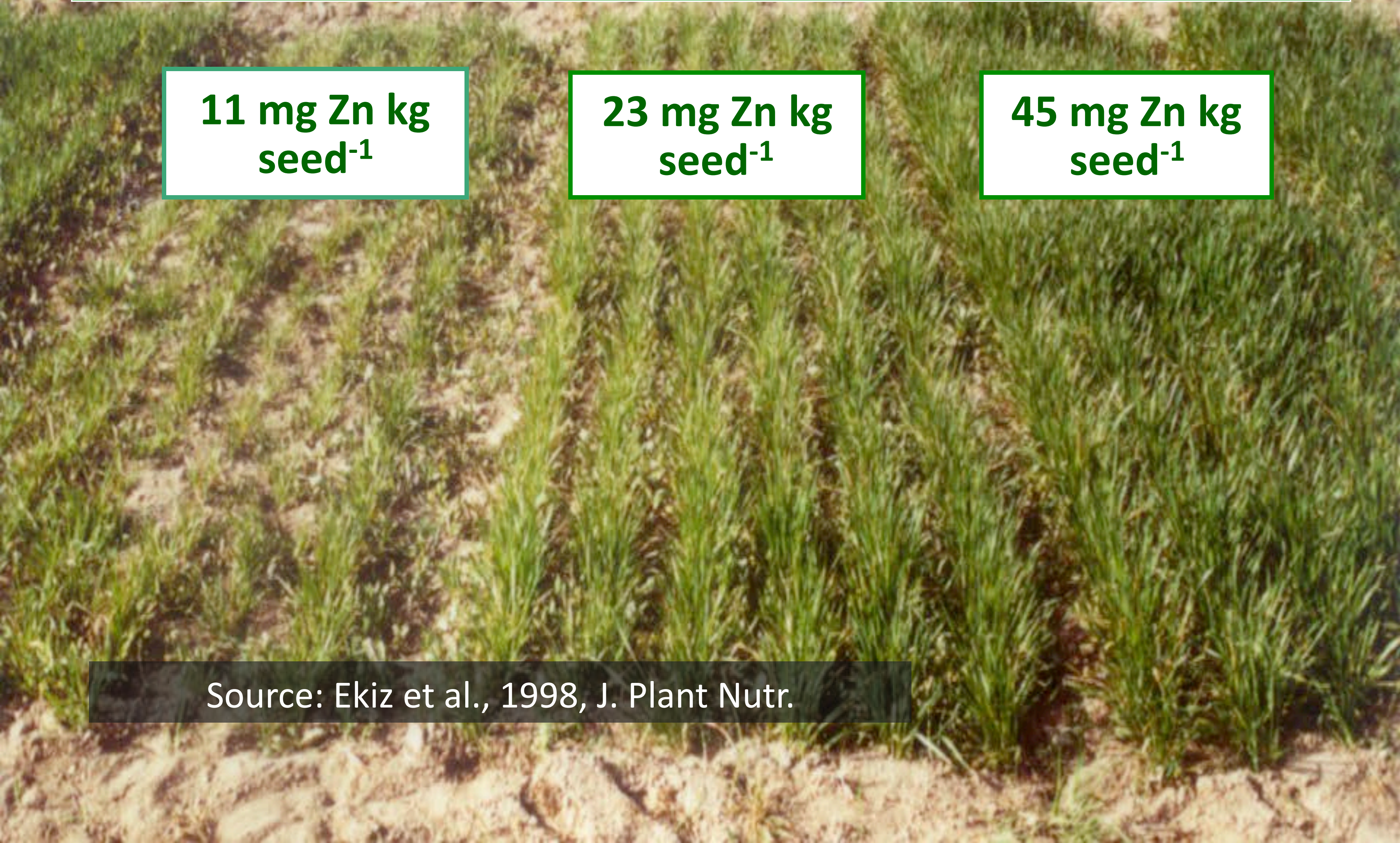
Conclusions-canola study

The results demonstrate that although canola has very **small seeds (about 3-4 mg per seed weight**) compared with wheat (about 30-35 mg per seed weight), Zn reserves existing in very small canola seeds still have a strong impact on early vegetative growth.

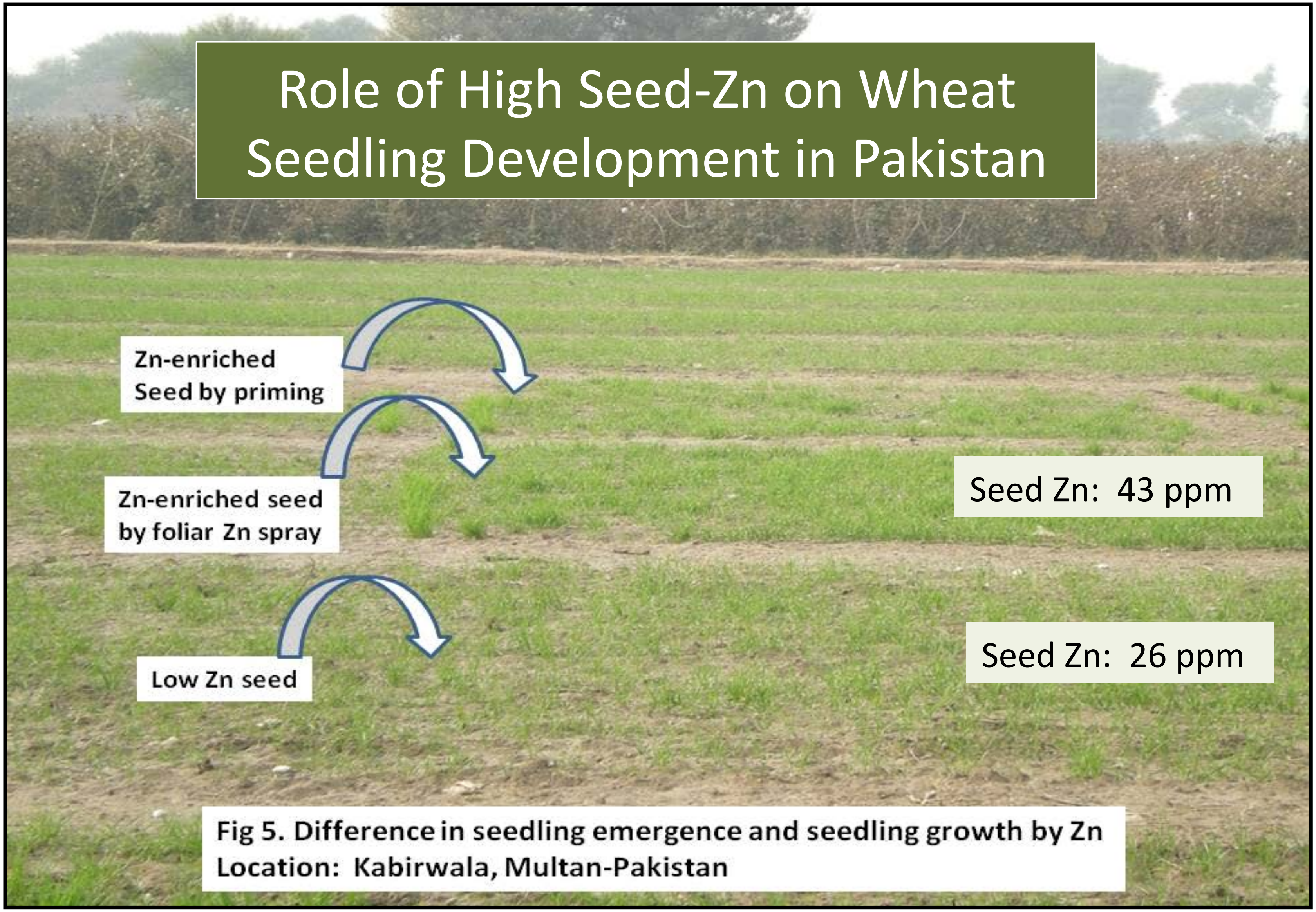
Seed having Zn concentration below 29 mg kg^{-1} dry weight of seed in canola is considered to be low in Zn. Low-Zn seed used in the the presented study had an average Zn concentration of 25mg kg^{-1} dry weight of seed.

Singh and Graham,1997,
Plant and Soil, 192: 191-197

Influence of Seed Zn Content on Growth of Bread Wheat in a Zinc-Deficient Soil in Central Anatolia

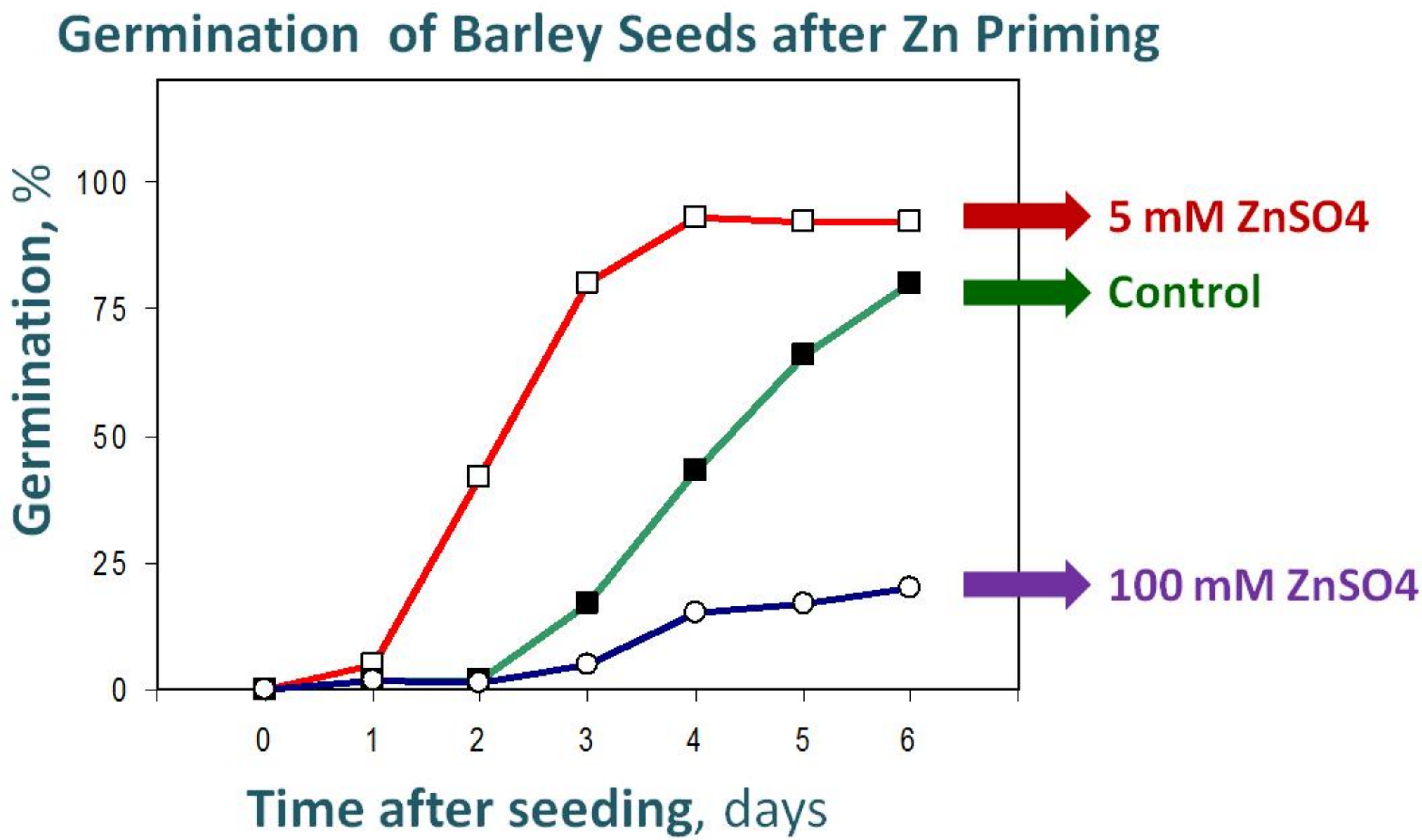


Source: Ekiz et al., 1998, J. Plant Nutr.



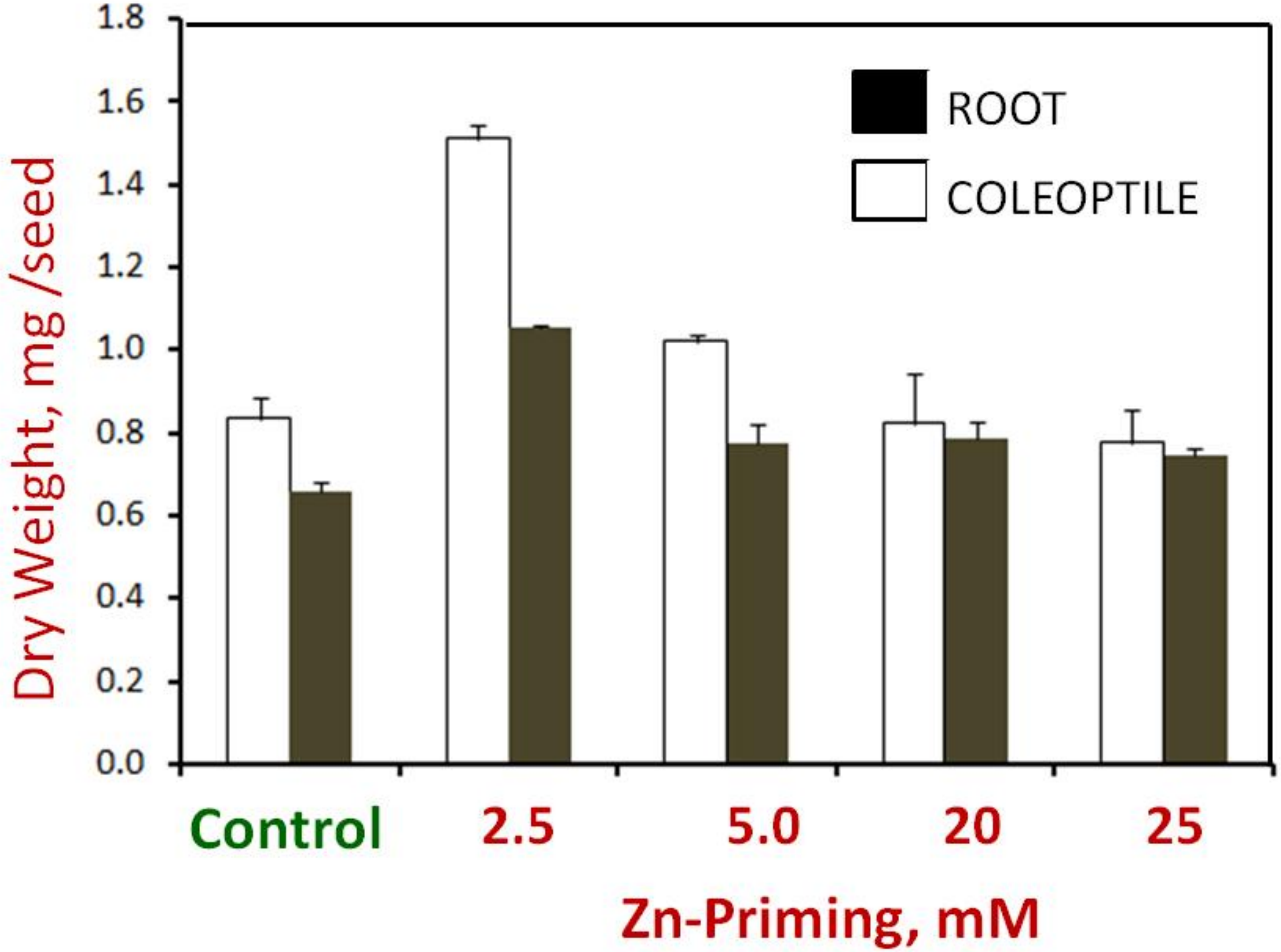
Picture: A. Rashid et al. 2012

Seedlings grown better when they raise from "*galvanized*" seeds



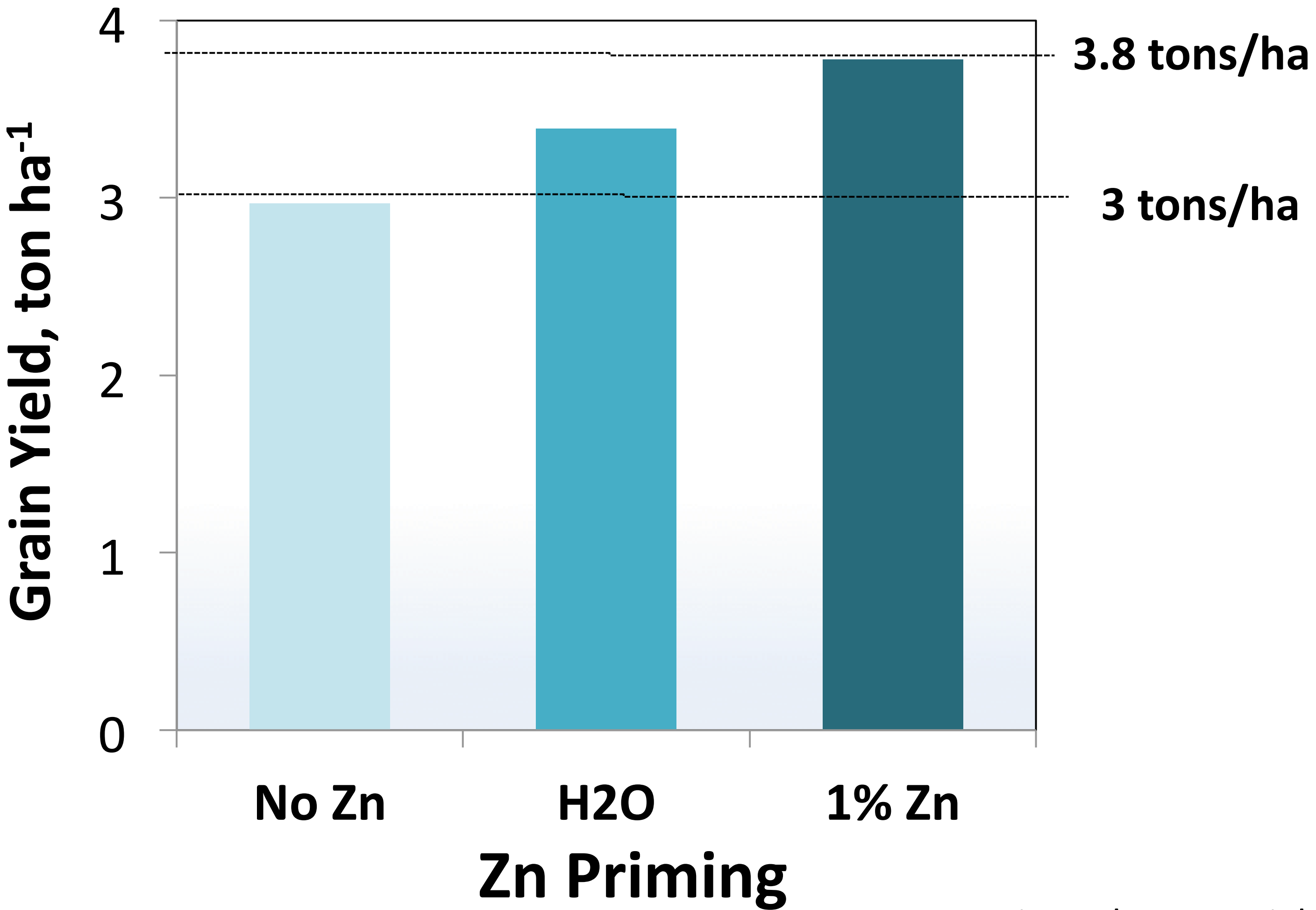
Ajouri et al., 2004, J. Plant Nutr. Soil Sci.167:630-636

Role of seed Zn priming in seedling growth of rice



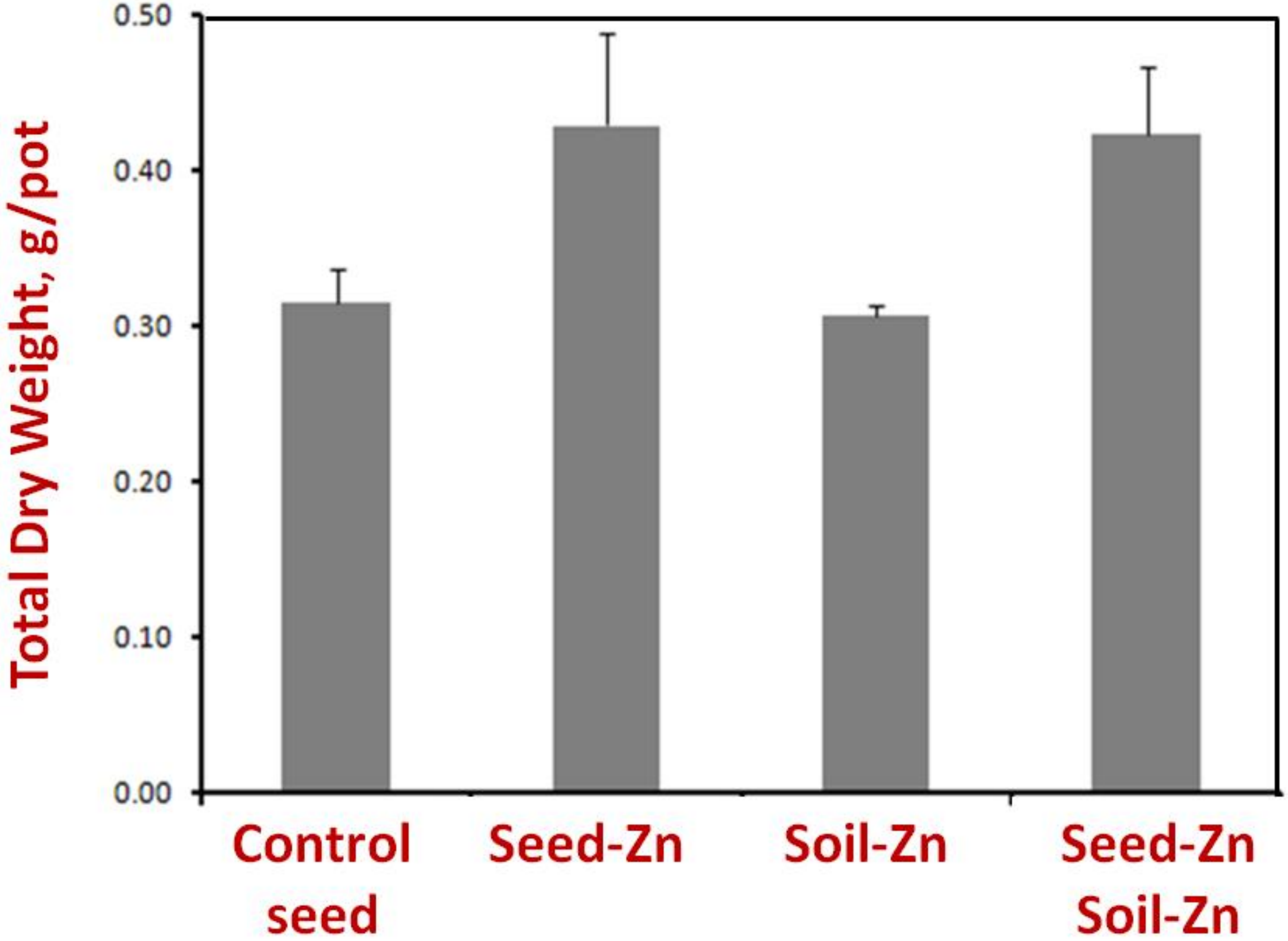
Prom-u-thai et al., 2012, J. Plant Nutr. Soil Sci. 175, 482–488

Average maize yield of seven field tests in which seeds used were primed with Zn (1.0 %) or without Zn priming



Harris et al., 2007, Field Crops Res. 102:119–127

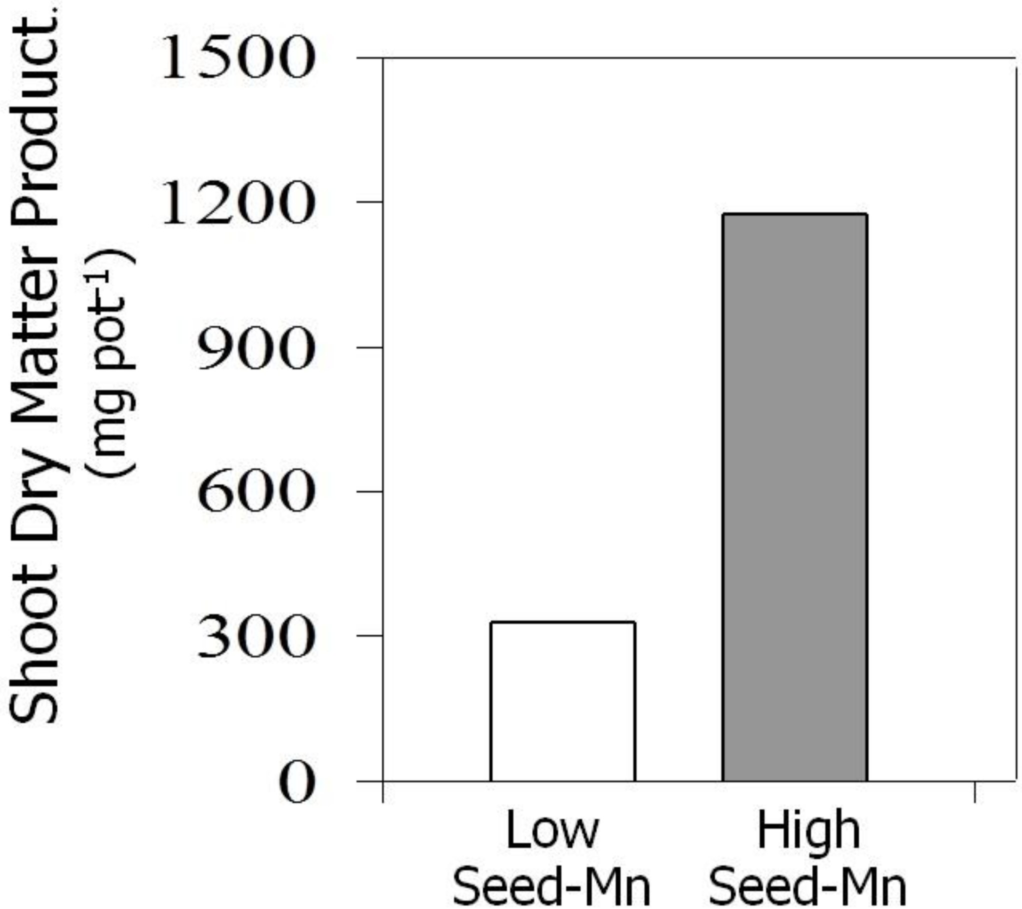
Effect of seed Zn priming (2.5 mM) and soil Zn application (2 ppm) on seedling growth of rice



Prom-u-thai et al., 2012, J. Plant Nutr. Soil Sci. 175, 482–488

Adverse effects of low micronutrients on seedling establishment and seedling vigor could not be always reversed by soil application of micronutrients fertilizer, **suggesting a potential damage at the cellular level caused by low concentration of micronutrients during seed development.**

Effect of Seed-Mn and Soil-Mn on Shoot Dry Matter Production of Wheat



Moussavi-Nik et al., 1997; In: Plant Nutrition-For Sustainable Food Production and Environment, Kluwer Academic Publishers, pp. 267-268.

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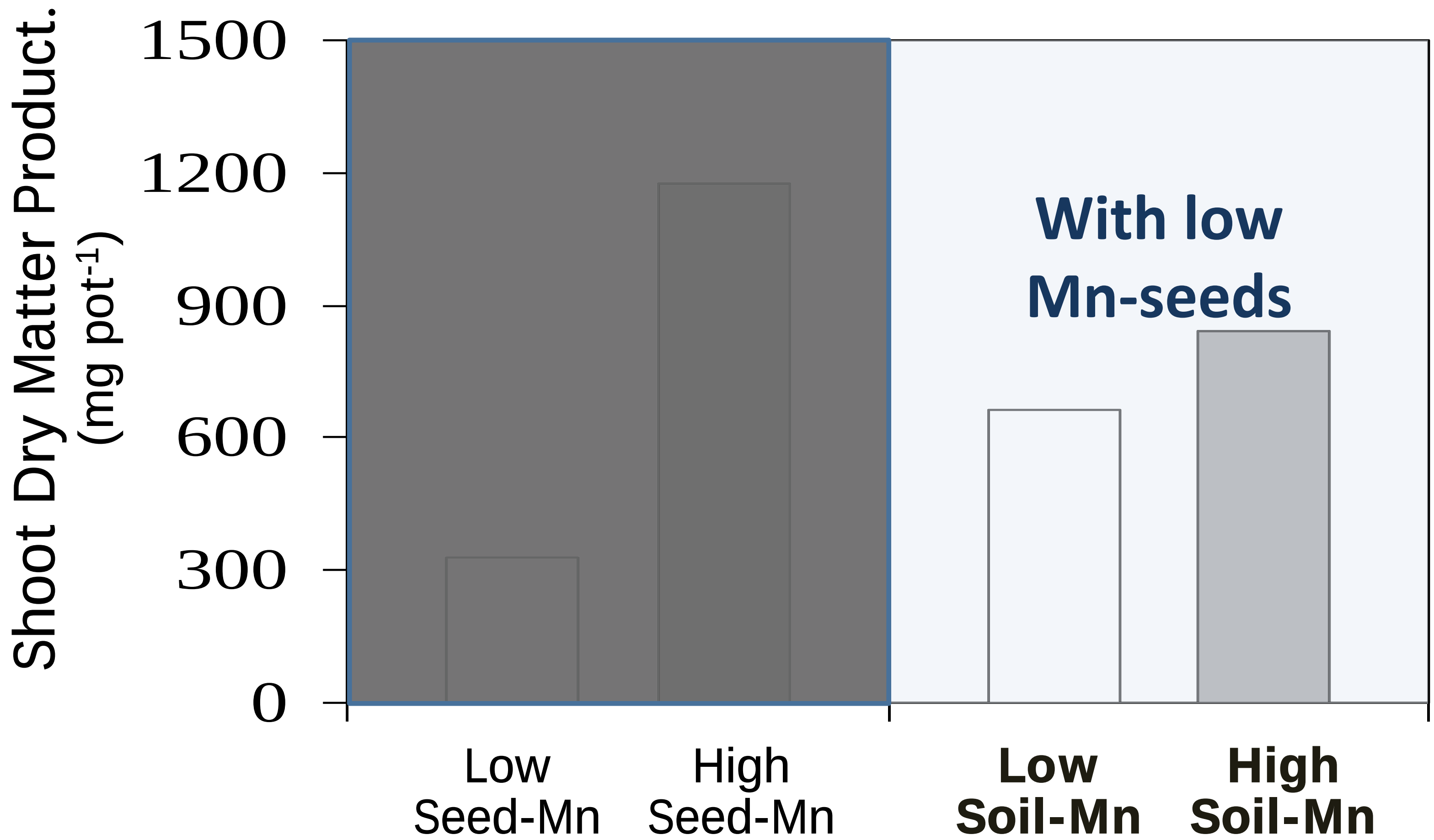

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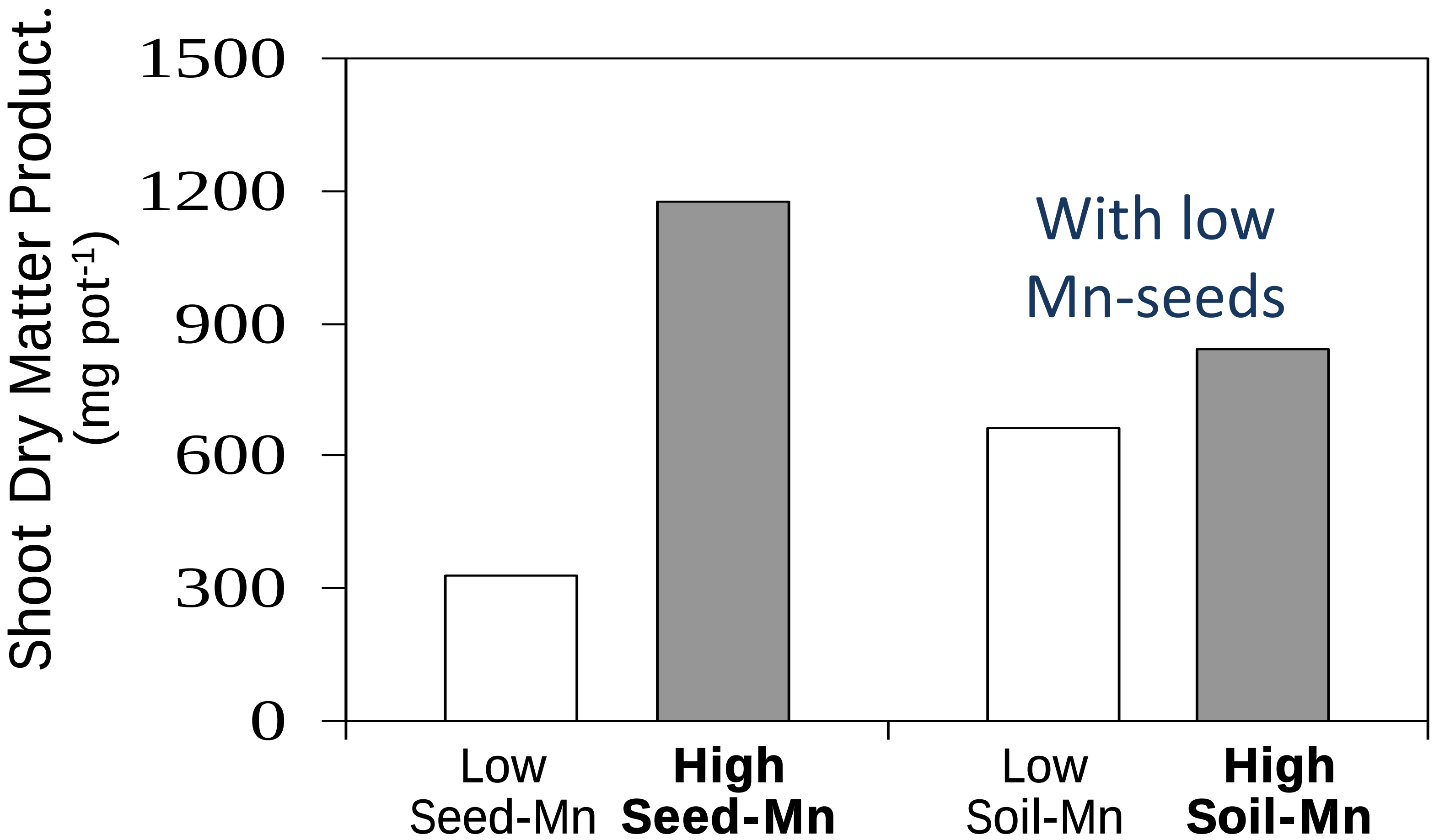
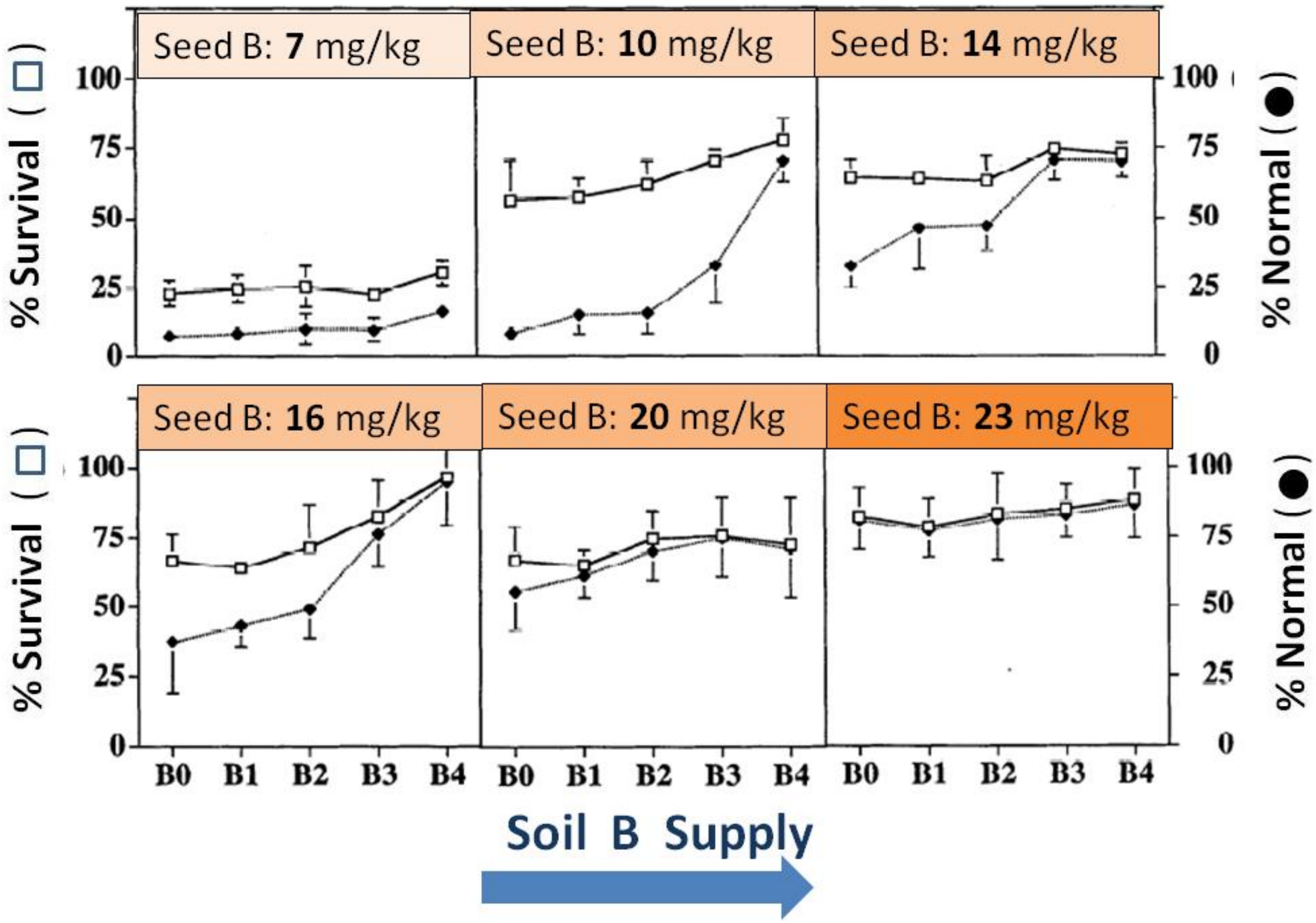


Moussavi-Nik et al., 1997; In: Plant Nutrition-For Sustainable Food Production and Environment, Kluwer Academic Publishers, pp. 267-268.

Seed-Boron

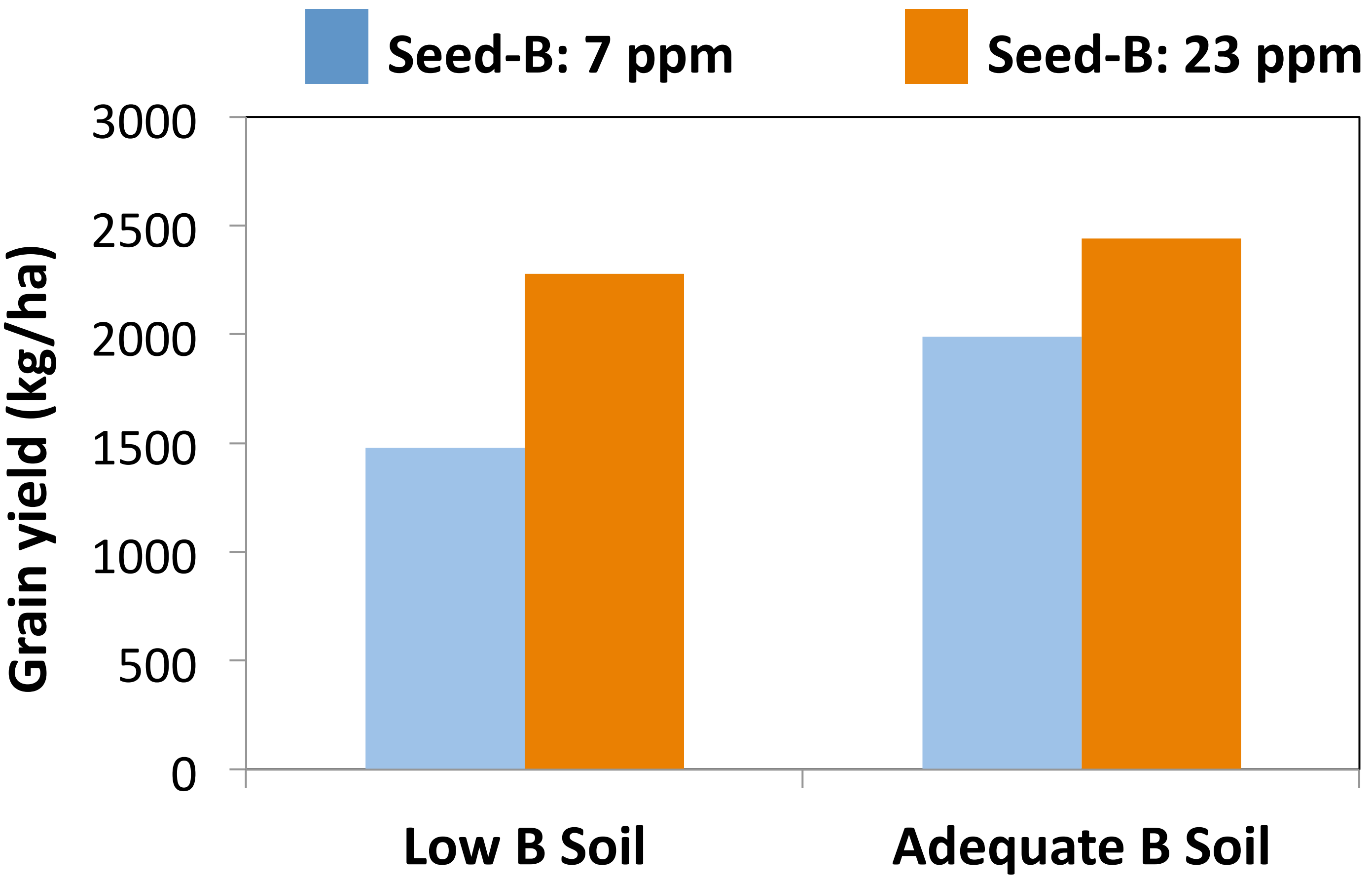
Like seed-Zn, also seed-B reserves play critical role in seed viability, seed germination and seedling vigour

Percentage of seedlings classified as as survived or as normal upon seed B concentrations and soil B applications in soybean



Rerkasem et al., 1997, Nutr. Cyc. Agroecosystems, 48: 217-223

Effect of seed-B and soil-B status on soybean grain yield under field conditions



Rerkasem et al., 1997, Nutr. Cyc. Agroecosystems, 48: 217-223

Conclusions-seed boron

Soybean seeds with B concentrations 10 mg B kg^{-1} have deformed cotyledons. **Seed with 7 mg B kg^{-1} performed poorly, with 80% failing to germinate and did not respond to soil B supply.**

Soybean seeds with a low concentration of B have permanently damaged seed embryos, preventing their germination or producing defective seedlings.

The critical concentration of B in soybean seed for permanent damage was between 7 and 10 mg B kg-1, and for normal seedling development in low B soils was between 14 and 20.

Seed Priming with Boron

Seed priming refers to the pre-sowing technique of moderately hydration of seeds to a point at which germination-related metabolic processes begin but radicle emergence does not occur

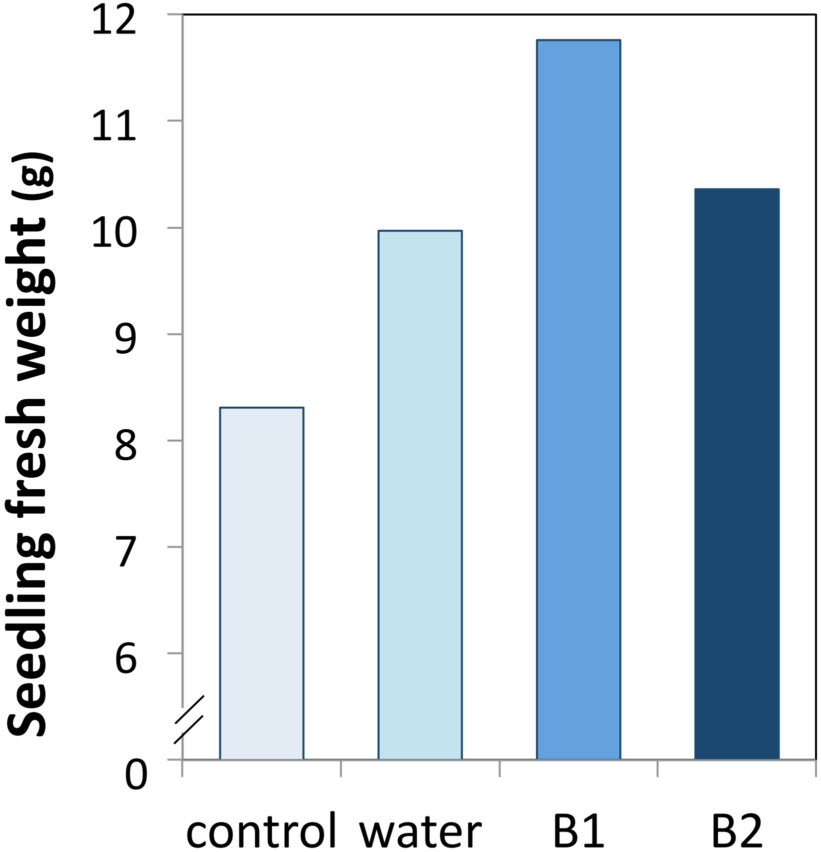
Priming of Rice Seeds with Boron:

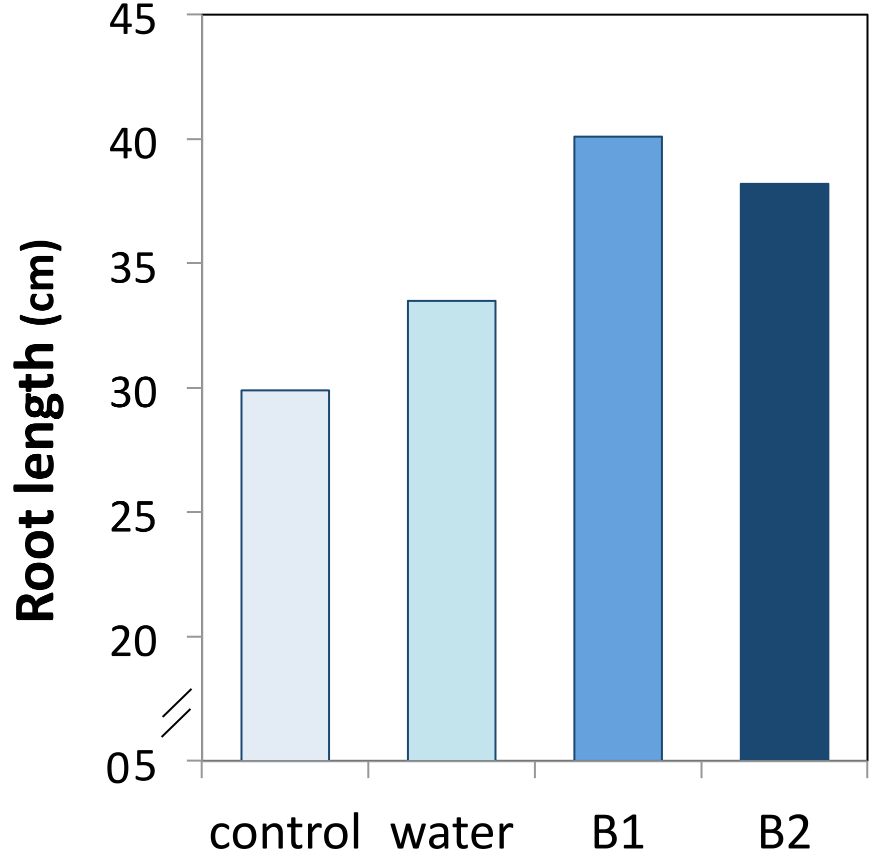
- ❑ Around 100 g rice seeds of seeds was soaked in aerated solution of 0.001 and 0.01 % B solutions (w/v) for 24 h (1:5, w/v).
- ❑ Water-control seeds were soaked in water (**hydropriming)** for 24 h.
- ❑ Untreated seeds were taken as **control**.

Boric acid was used for B priming treatments

Growth of rice seedlings at at two levels of boron priming:

B1: 0.001 % Boric Acid; B2: 0.01 % Boric Acid





Rehman et al. 2012, Plant Growth Reg. 68: 189-201

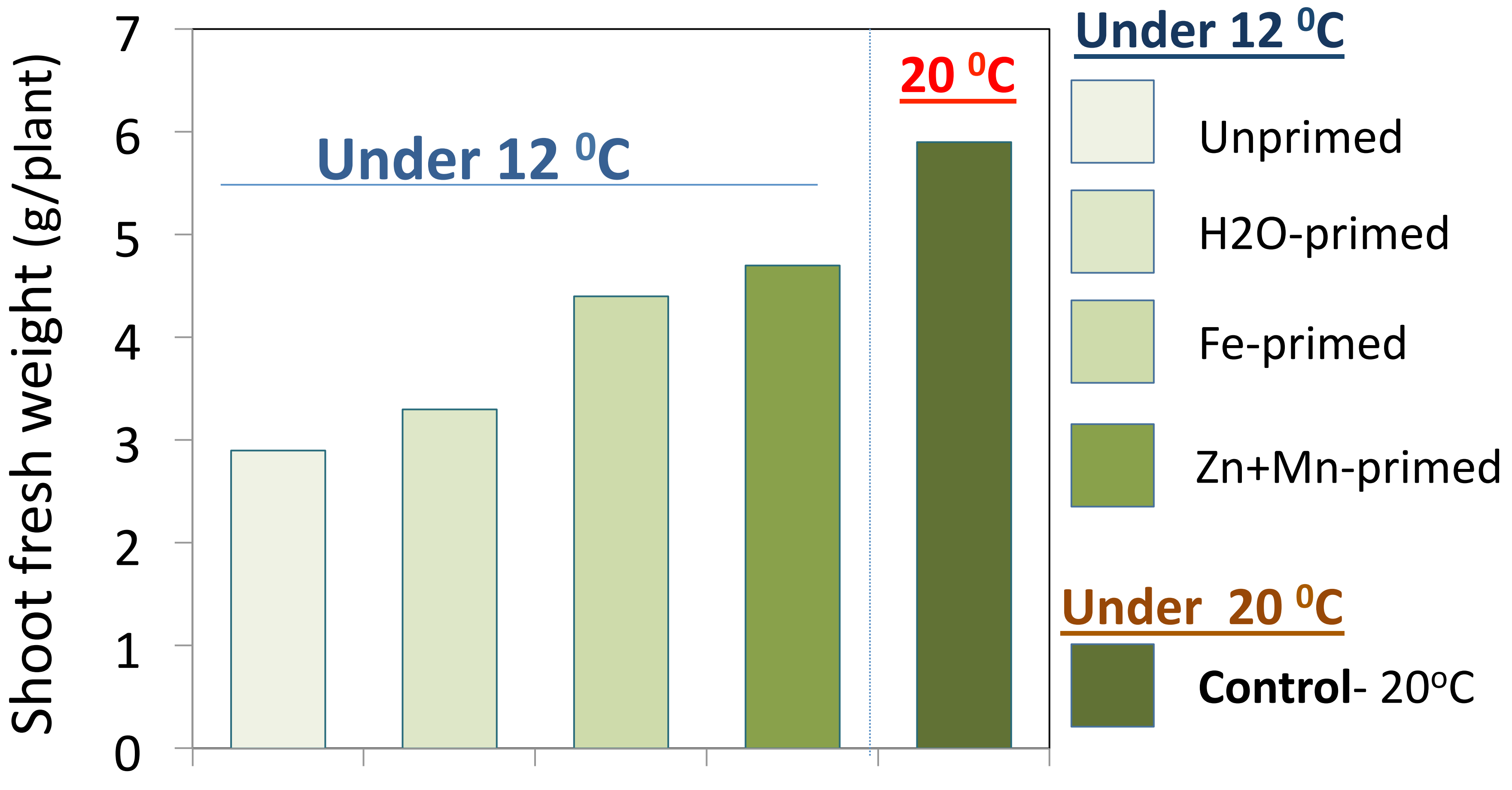
Stress Tolerance

Increasing evidence is available showing that seed priming with micronutrients contribute to stress tolerance of germinating seeds.

Low root zone-temperature in early spring is a major constraint for crop production in many regions, especially in Central and Northern Europe and North America/Canada.

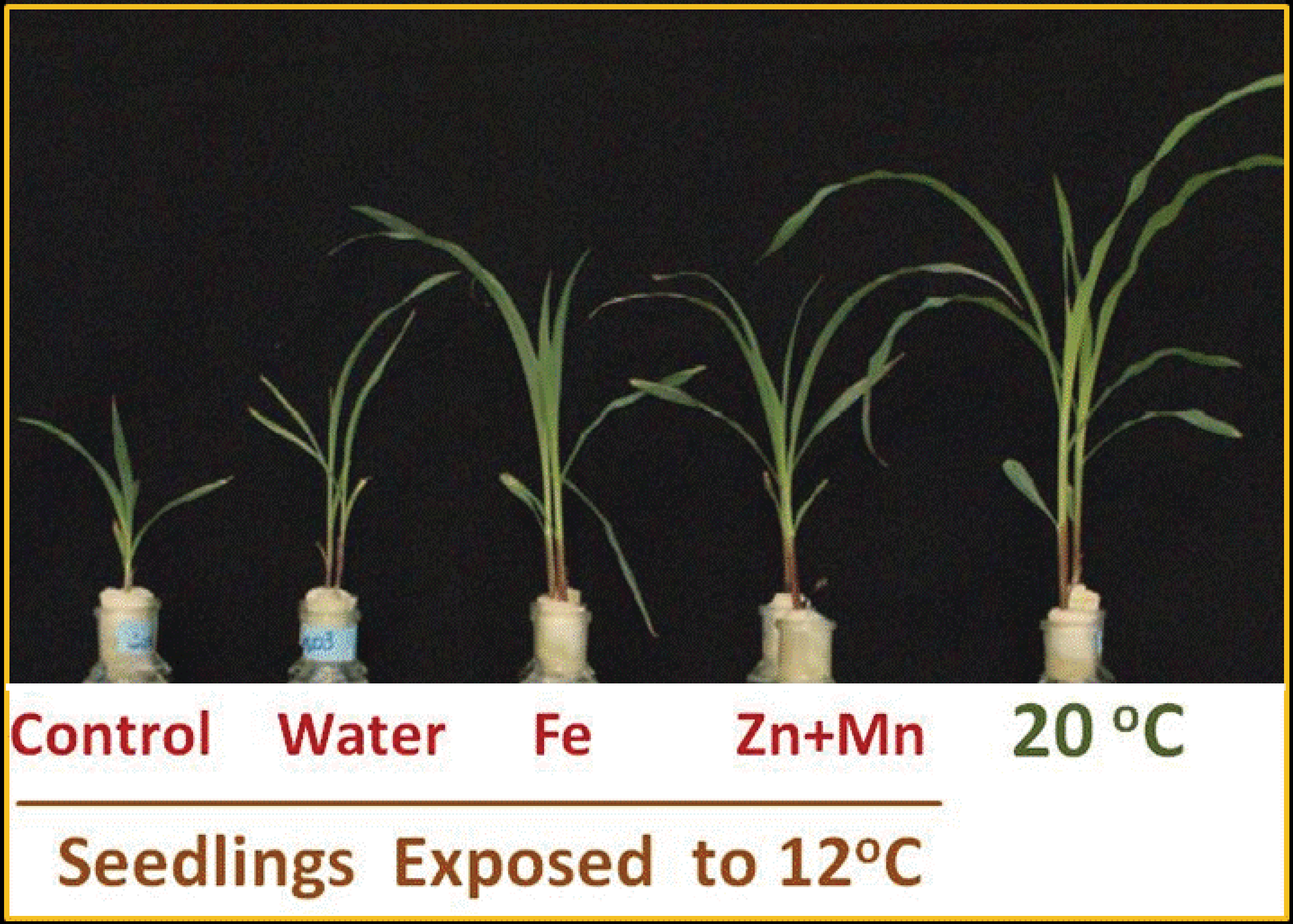
Recently, an experiment has been conducted to study role of seed priming with micronutrients in mitigation of adverse effects of low soil temperature.

Shoot fresh weight of maize plants **at low (12 ^{0}C) and high (20 ^{0}C) root zone temperature** following priming of seeds with micronutrients



Imran et al. 2013, Europ. J. Agron. 49: 141-148

Growth of maize plants **at low (12 ^{0}C) and high (20 ^{0}C) root zone temperature** following priming of seeds with micronutrients



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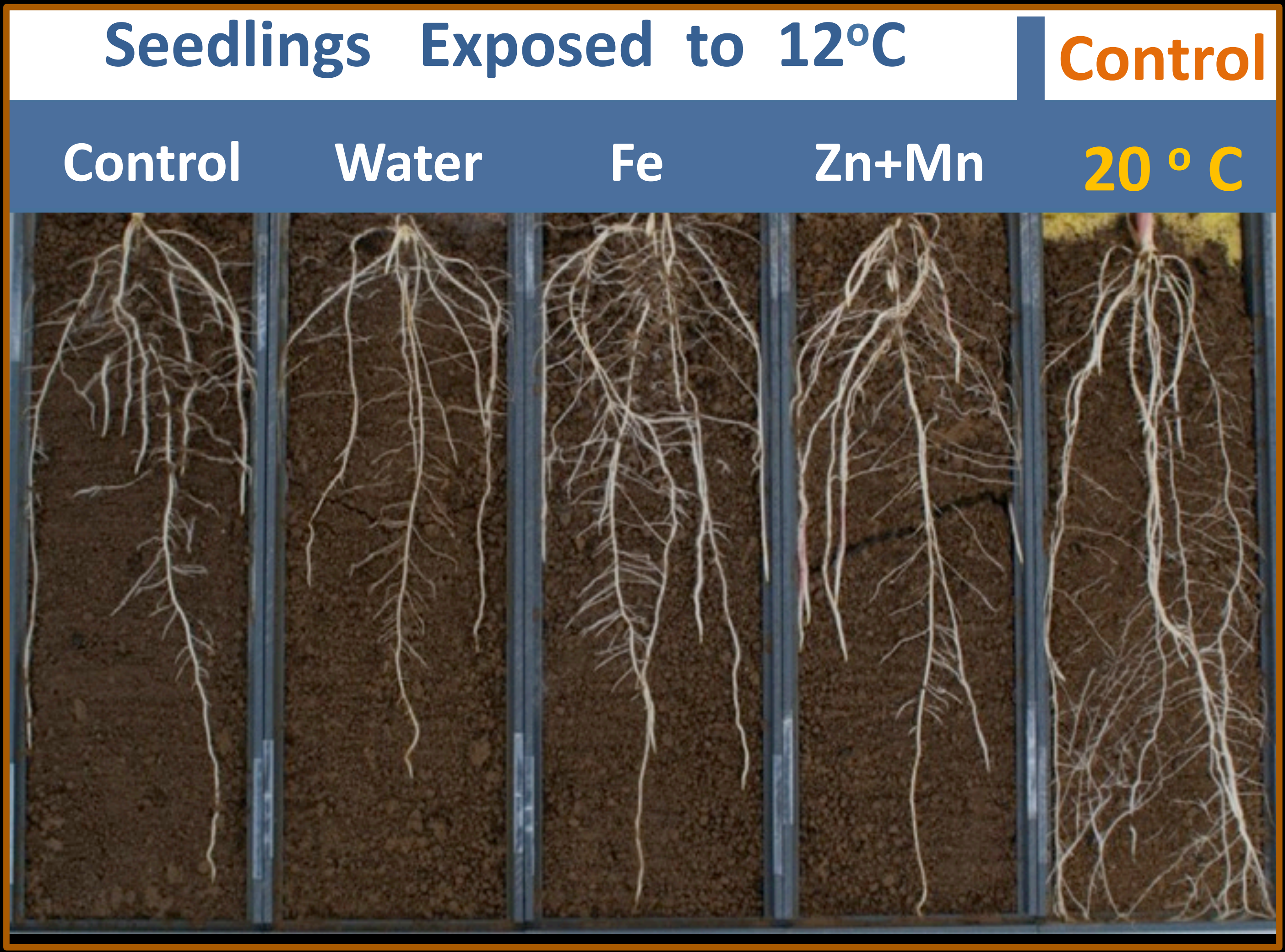
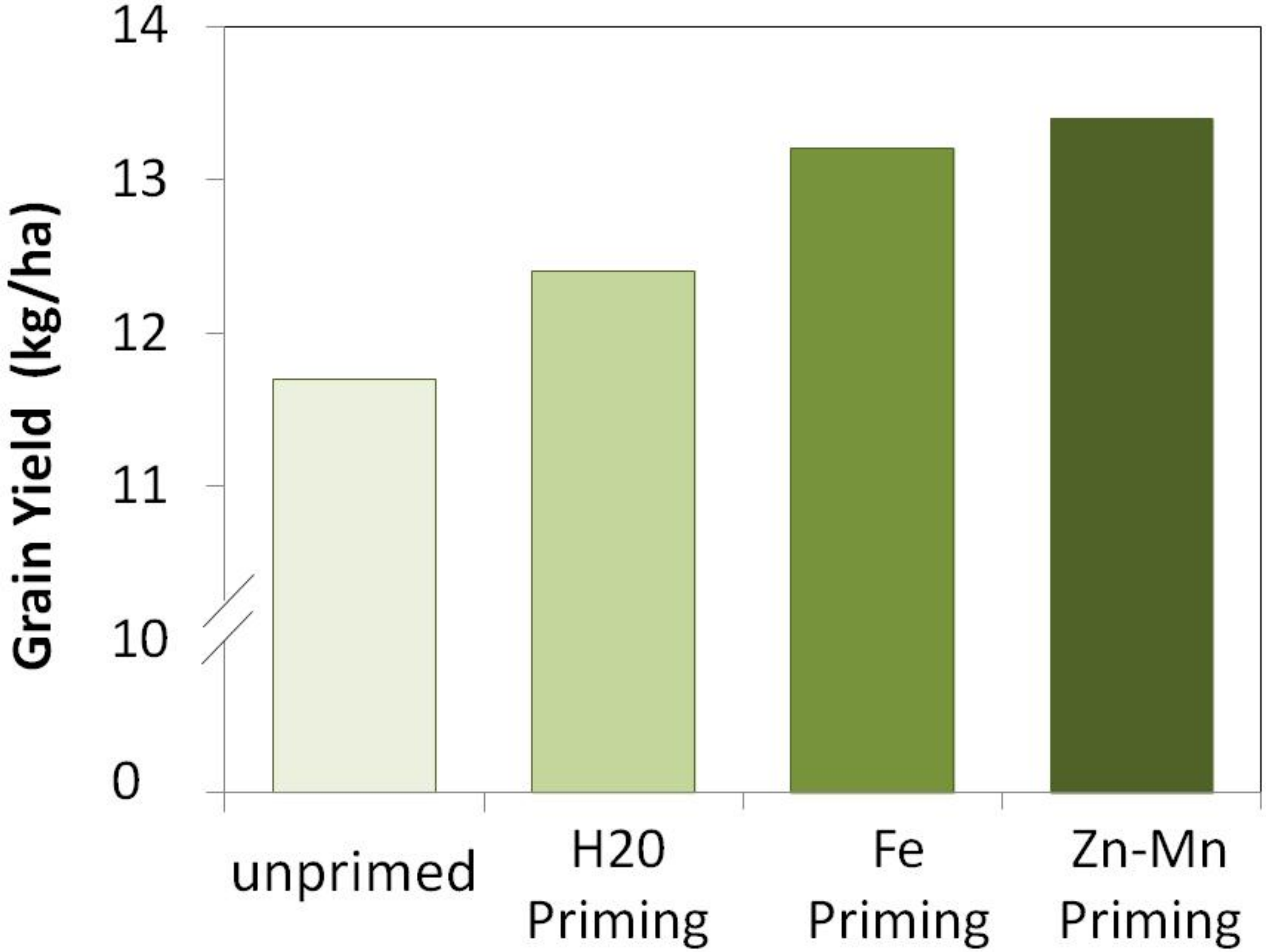


Imran et al. 2013, Europ. J. Agron. 49: 141-148

Grain yield of maize grown under field conditions after priming seeds with different micronutrients



Imran et al. 2013, Europ. J. Agron. 49: 141-148

Seed Nickel

Nickel is the cofactor of urease, which is still the only known Ni metalloenzyme in plants (Marschner, 2012)

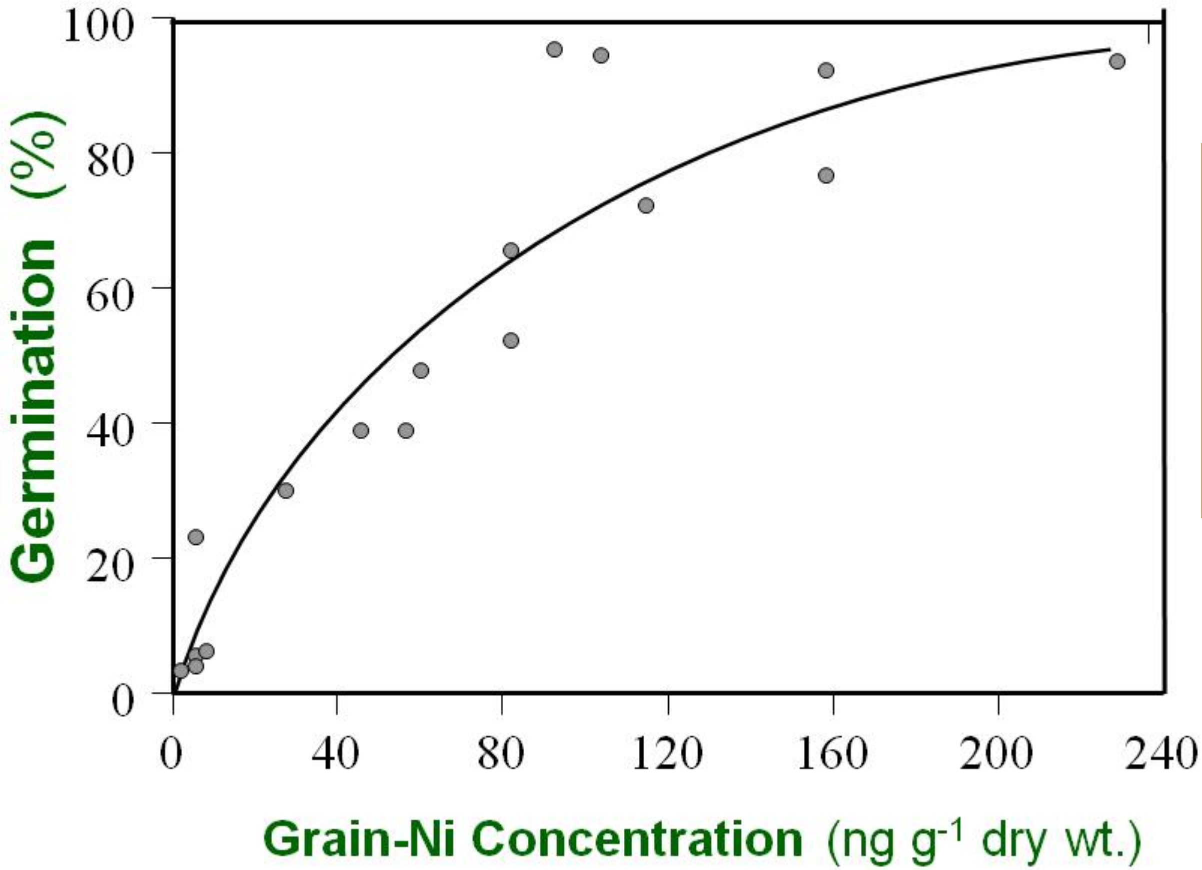
Urease catalyzes the breakdown of urea into ammonia

$$CO(NH_2)_2 + H_2O \xrightarrow{\text{urease}} NH_3 + NH_2COOH$$

$$NH_2COOH \xrightarrow{\text{spontaneous}} NH_3 + CO_2$$

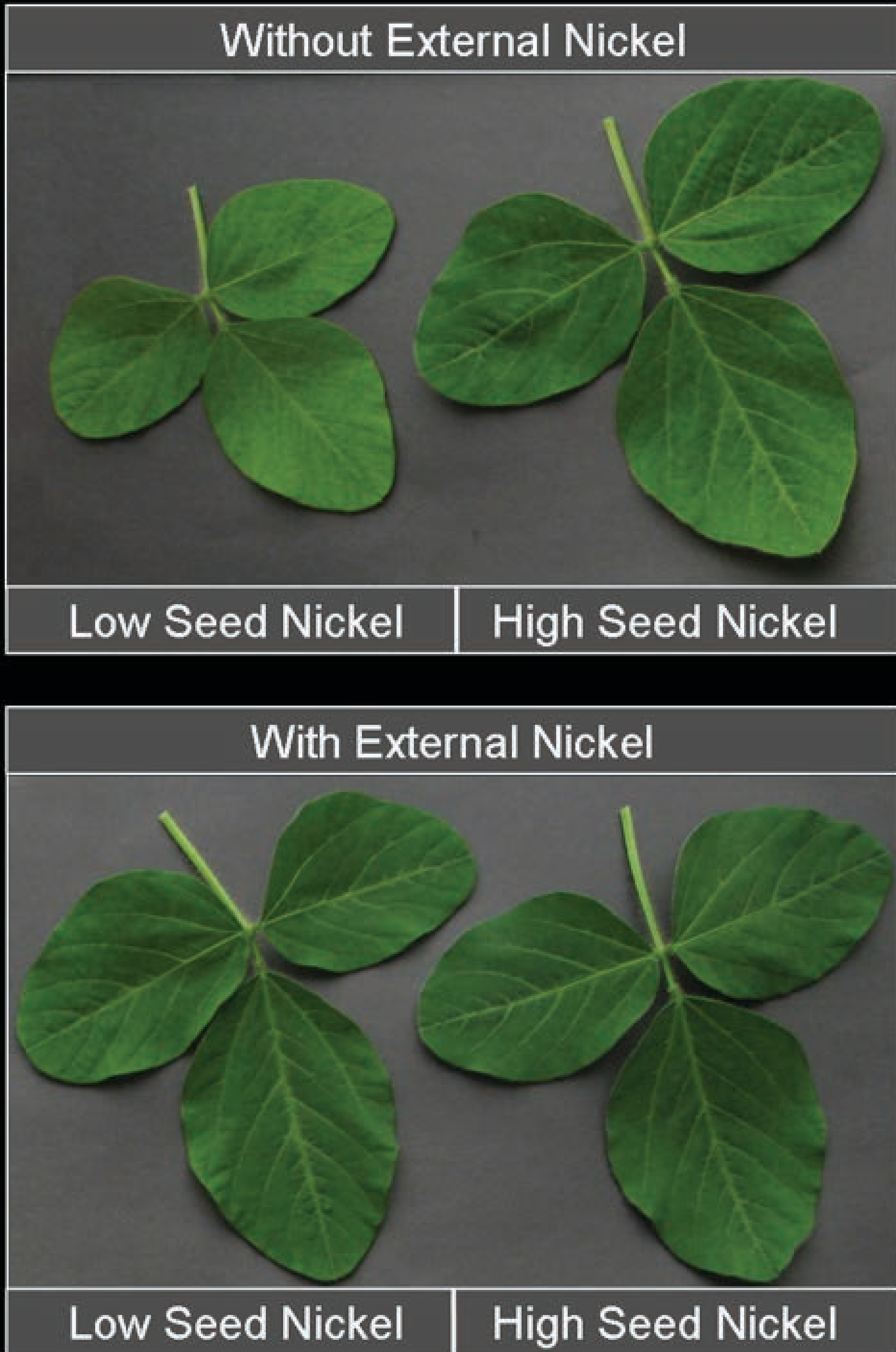
It is widely accepted that there are other, but not well-documented, functions of Ni in plant systems

Effect of Ni Concentrations in Barley Grain on Grain Viability/Germination



Barley seeds containing negligible Ni failed to germinate adequately

Welch, 1999, In: Mineral Nutrition of Crops. Fundemental Mechanisms and Implictions, Food Products Press)

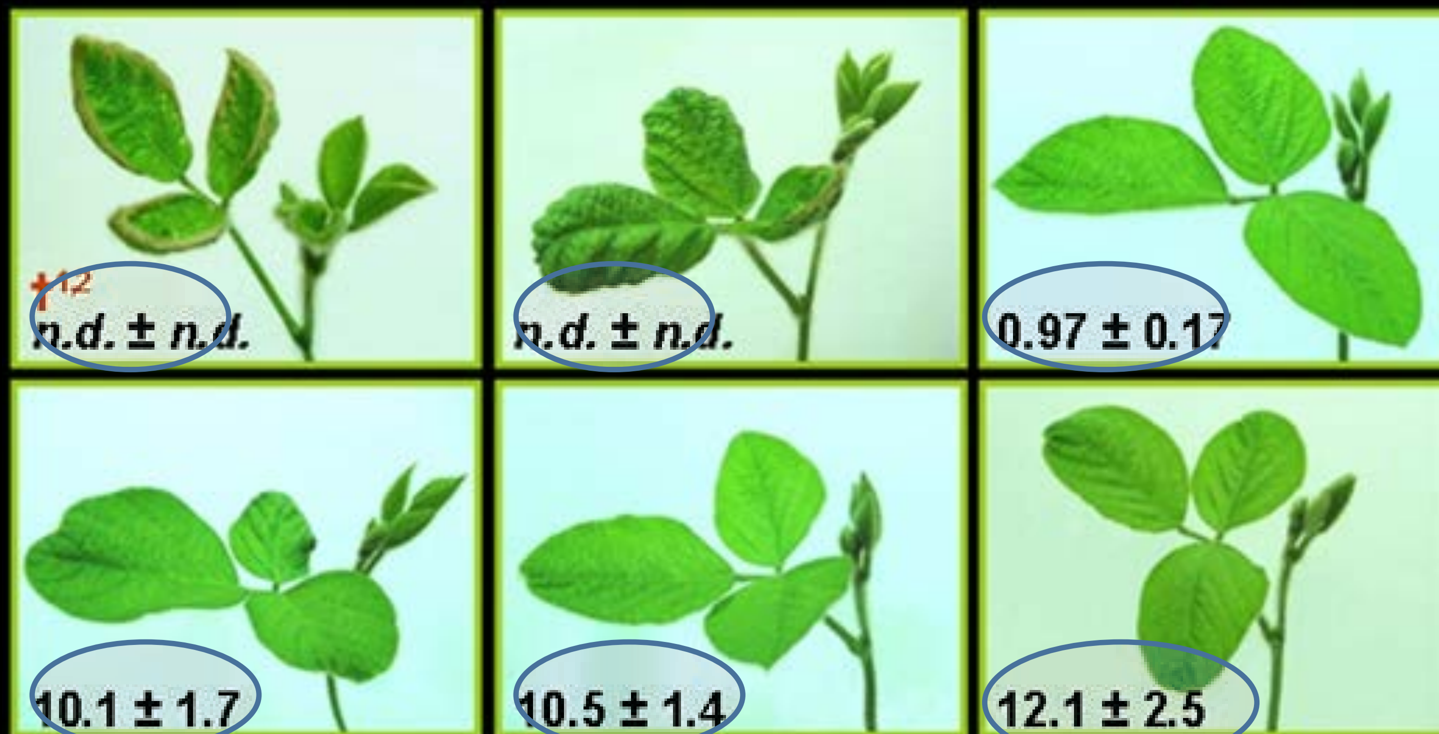


Impact of seed Ni on leaf growth of soybean plants with and without external Ni application

Kutman et al., 2014, Plant and Soil, in press

Toxicity symptoms in youngest parts of 28-day-old urea-sprayed (2 %) soybean plants raised from seeds differing in Ni

	Low Ni seed	Medium Ni seed	High Ni seed
No Ni Application			
With Ni Application			



Leaf Ni concentrations, ppm

Kutman et al. 2013
Plant Soil, 363: 61-75

Effect of seed Ni content on shoot dry weight at 56 days, seed yield and leaftip necrosis

Seed Ni	Shoot Dry Wt	Seed Yield	Leaf Tip Necrosis
(ng Ni/seed)	g $plant^{-1}$	g $plant^{-1}$	%
2.5	27.0	14.1	25.6
13	29.5	14.9	20.0
160	21.7	21.7	1.0

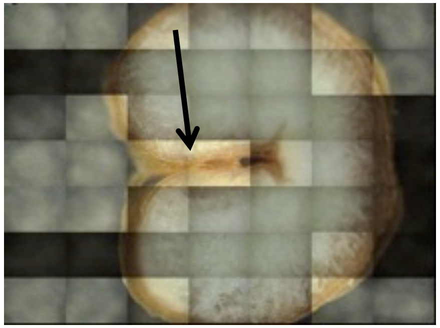
Eskew et al., 1984; Plant Physiol. 76: 691-693

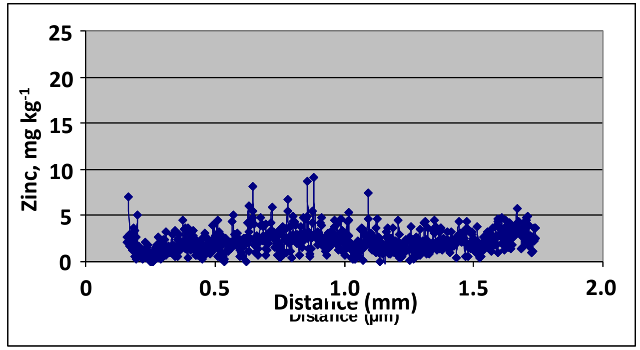
Conclusions

Avoiding nutrient deficiencies on maternal plants, especially during late growth season, is important not only for better yield but also for better seed viability and vigour. Therefore, keeping high plant available nutrient concentrations in soil and/or in plant tissues during the reproductive growth stages (e.g., through foliar spray) may greatly contribute to high seed nutrient reserves **(Example: Zn-slide)**

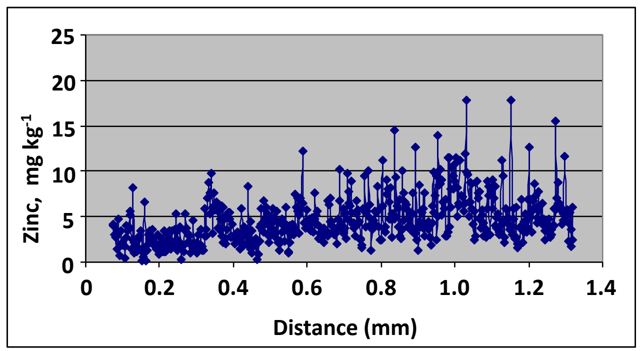
When seeds with low nutrient density are sown, the ability of new crop to withstand environmental stress factors in the early growth stages is often impaired.

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

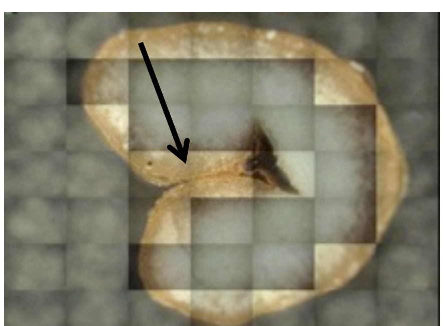


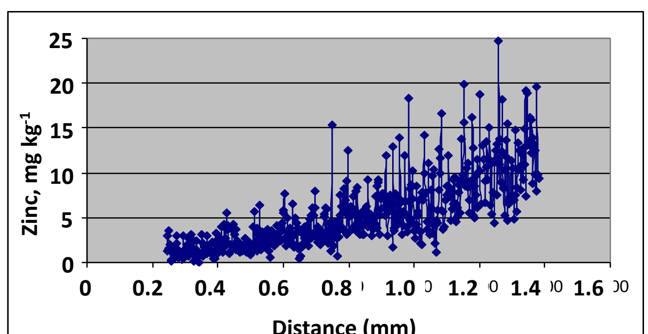


No Foliar Zn Application



Foliar Zn Spray at Stem Elongation and Booting Stages





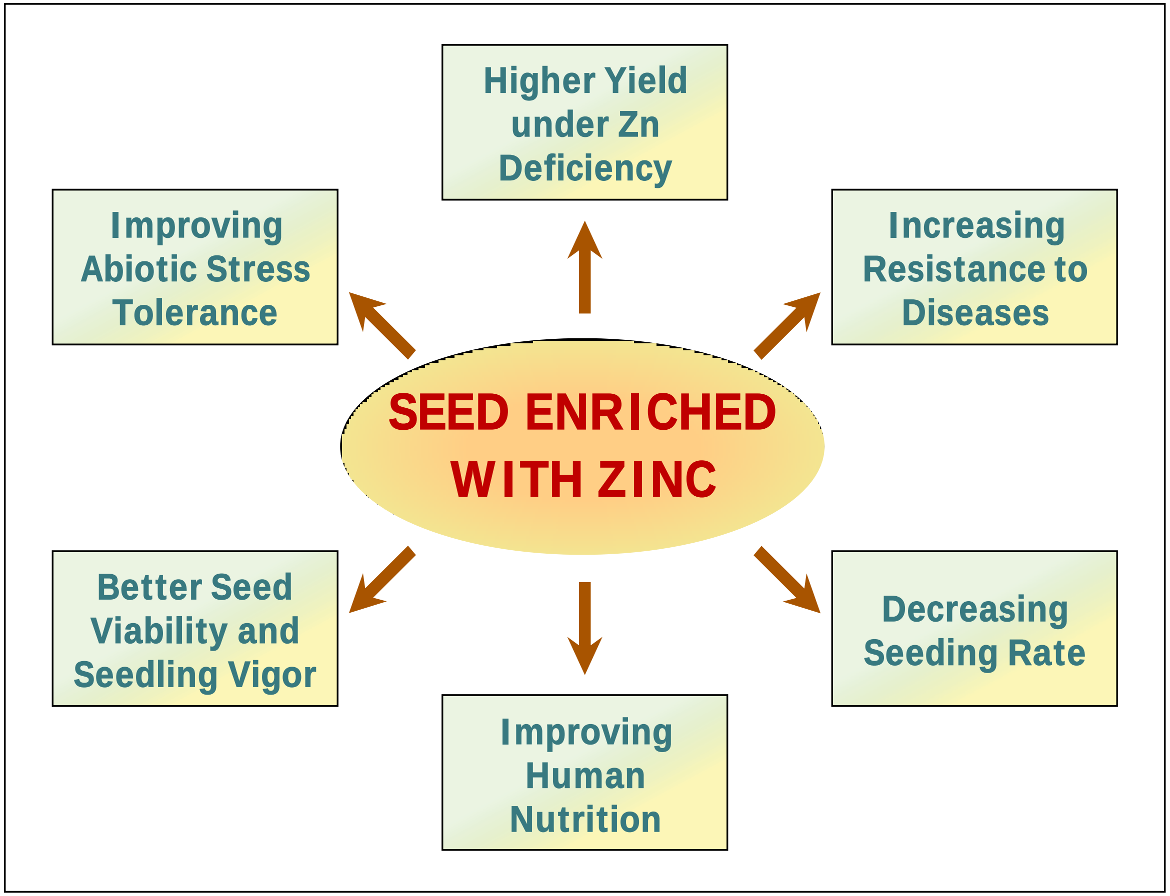
Foliar Zn Spray at Milk and Dough Stages

Cakmak et al 2010, J. Agric. Food Chem. 58: 9092-9102

In most cases, germination and/or a good seedling vigour failed to respond to increasing levels of soil nutrient supply, suggesting that seed embryos have been apparently damaged by nutrient deficiencies during seed development on the parent plant.

Soil and foliar fertilization practices should also include the aspects of seed nutrition (**seed fertilization**). Like soil and foliar fertilization, also the "**seed fertilization**" concept should be developed and established.

This concept may open new collaborative research areas and discussions between fertilizer and seed industries; and has also highly important implications for human nutrition.



Agronomic and human nutritional benefits associated with high seed Zn (Cakmak 2008, Plant and Soil)