Seed fertification: An approach to improve low temperature stress in maize

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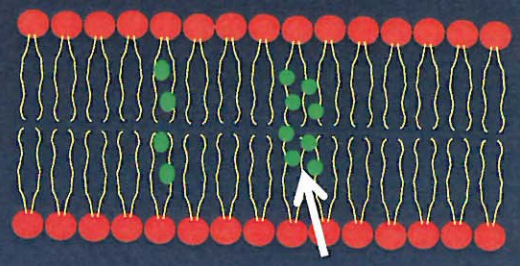
Role of micronutrients in stress tolerance in plants

Biotic and abiotic stresses damage plant cells by:

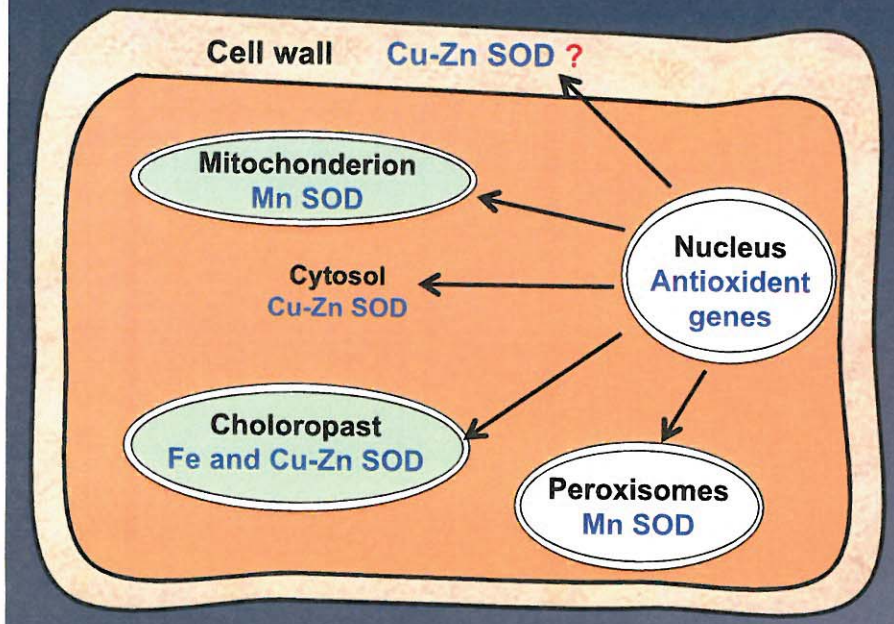
- Generation of free radicals leading to oxidative stress
- Damage to plasma membranes



Micronutrients improve stress tolerance in plants by:

- Maintaining membrane stability
- Protection against oxidative stress (Synthesis of phenolic compounds, superoxide dismutases (SODs),)

SODs in different cell compartments



Alscher et al., 2002

Effect of B on membrane leakage in sunflower leaves

Cakmak et al., 1995

Approaches to increase seed nutrient contents

Seed biofortification (Expensive and time consuming)

- Conventional breeding
- Genetic engineering

Foliar nutrient application on crop plants (Expensive, laborious and time consuming)

- Pre-anthesis foliar application of micronutrients

Seed coating (Cost effective based on application method)

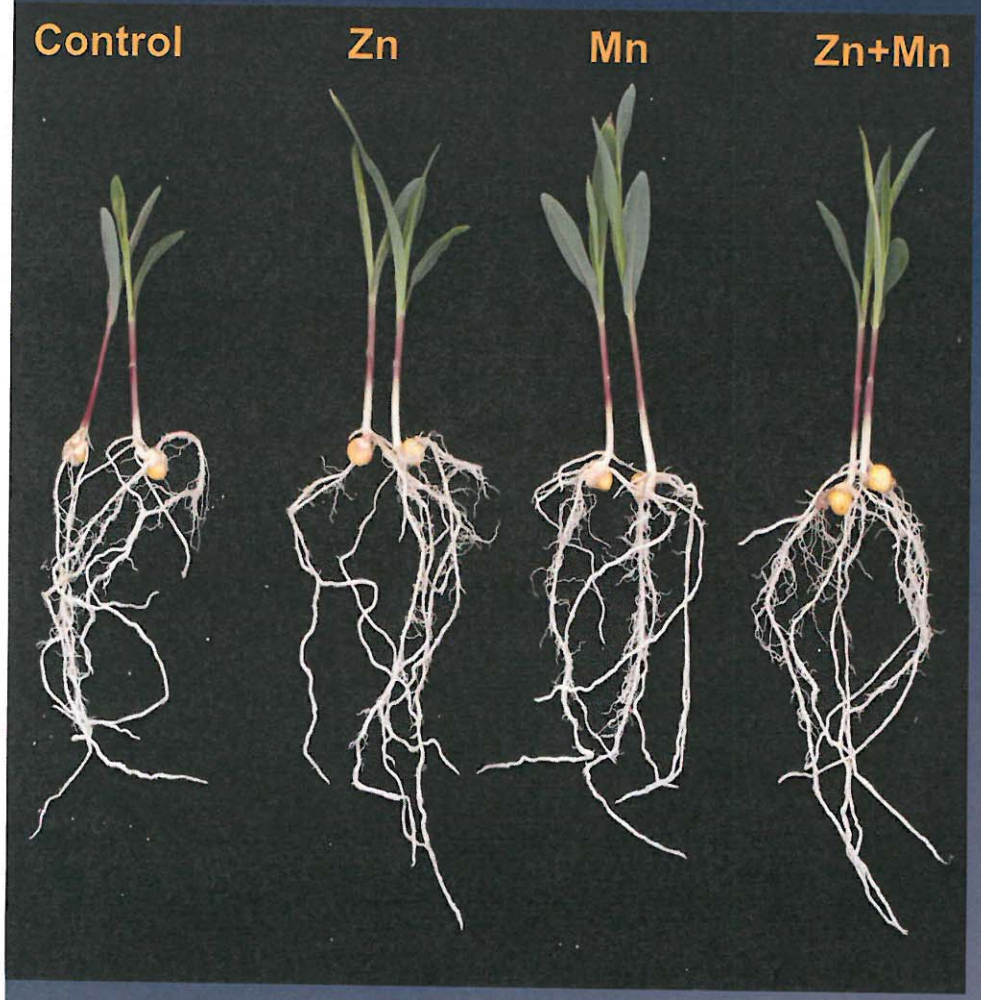
- With suspensions of mineral nutrients e.g. Nutri Seed®, Awaken® ST
- Nutrient combined with seed fungicide treatments

Nutrient seed priming (Seed fertification) (Cost effective, multi-beneficial)

- Soaking into nutrient solution for certain time duration and subsequent drying to storage moisture contents before further use

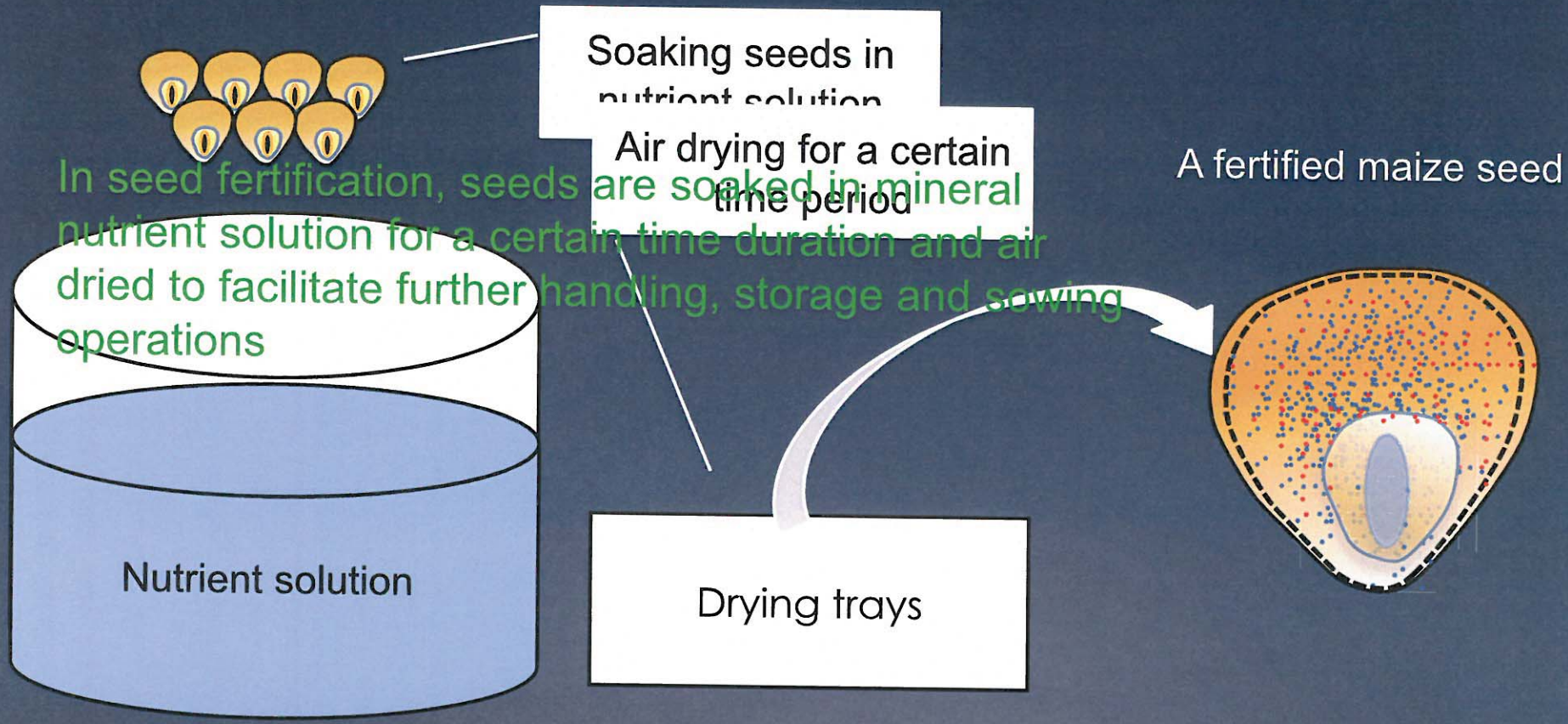
Effect of seed fertification on seedling development

1 week old maize seedlings developed in sand medium



Zn and Mn deficiency symptoms in soybean leaves

Process of seed fertification



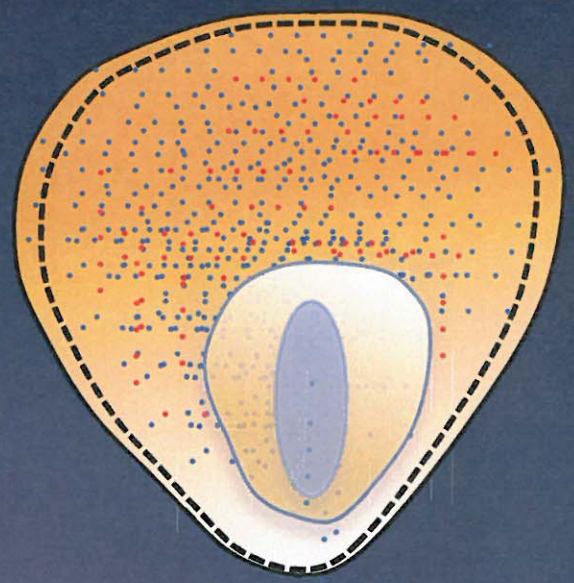
In seed fertification, seeds are soaked in mineral nutrient solution for a certain time duration and air dried to facilitate further handling, storage and sowing operations

Contents of nutrients in maize seeds after fertification

Mineral nutrient contents in maize seeds

Mineral nutrients in seed	Unprimed (µg seed^{-1})	Nutrient primed (µg seed^{-1})
Zn	8.5 ± 0.4 a	52.7 ± 2.5 b
Mn	2.0 ± 0.1 a	18.1 ± 1.0 b
Fe	11.4 ± 0.4 a	14.7 ± 0.3 b
B	0.72 ± 0.2 a	7.08 ± 0.1 b
P	965 ± 23 a	1155 ± 37 b

Significant difference at $p < 0.05$

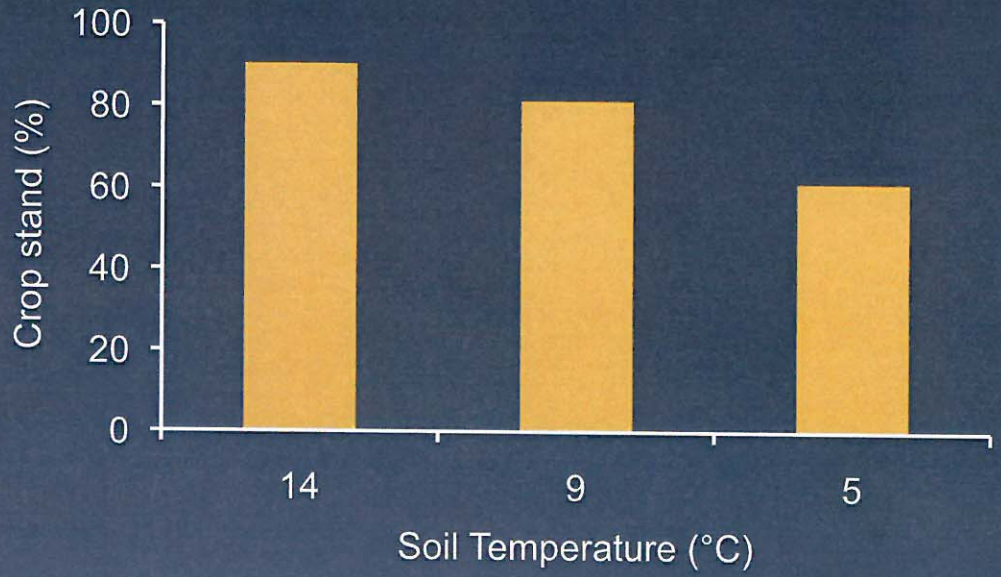


Mineral nutrient contents were significantly increased after fertification of maize seeds

Case study

Micro-nutrient seed priming increase tolerance to low root zone temperature (RZT) stress in maize

Impact of low root zone temperature (RZT) on maize seedling development



Effect of soil temperature on maize crop stand 4 weeks after sowing

(Pioneer Hi-bred)

Low RZT causes defective germination and development of abnormal seedlings leading to poor crop stand establishment

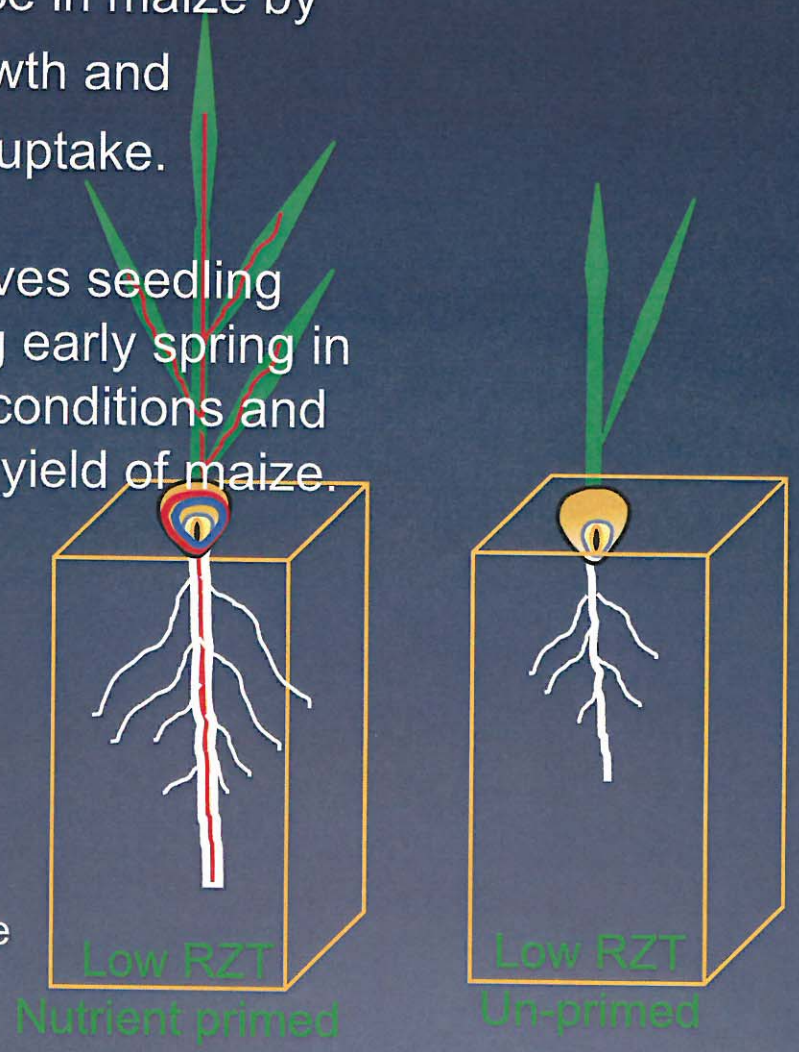
Hypotheses

Micronutrient seed fertification improves Low RZT stress tolerance in maize by

(a) Increasing root growth and

(b) enhancing nutrient uptake.

Seed fertification improves seedling development during early spring in temperate climatic conditions and increase final grain yield of maize.



Schematic diagram: Role of micronutrient seed priming in improving low RZT stress in maize

Model experiments

One week old maize seedling from treated seeds were grown in solution and soil culture under low RZT stress

Solution culture

RZT:

Control	20 ± 2 °C
UP (Control)	12 ± 2 °C
WP (water)	12 ± 2 °C
Fe	12 ± 2 °C
Zn+Mn	12 ± 2 °C

Growth medium:

Complete nutrient solution (400 ml pot^{-1})
Changed every 2-3 days.

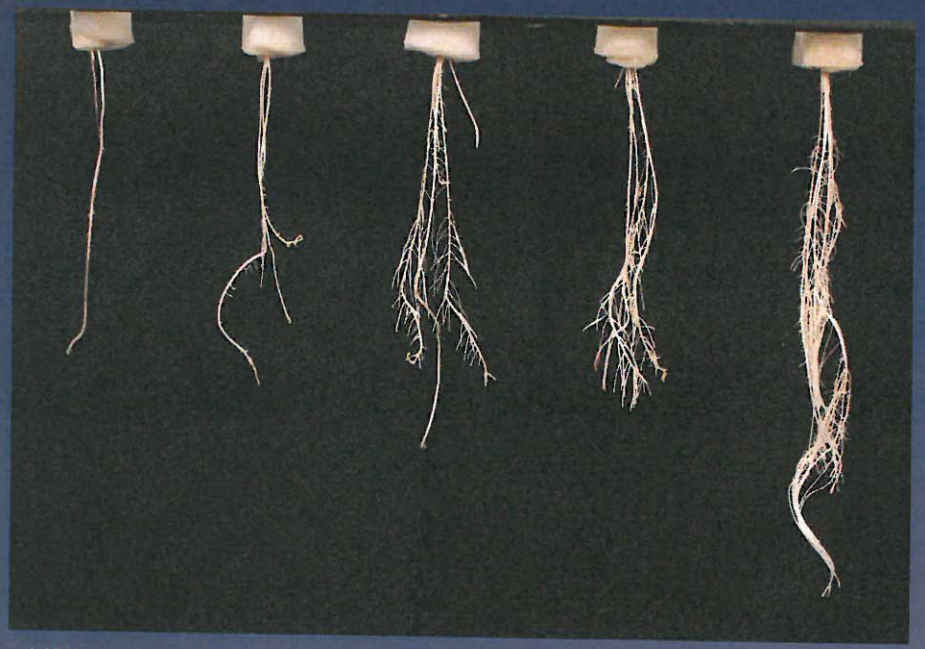
Soil culture (Rhizo-boxes)

Control	20 ± 2 °C
UP	12 ± 2 °C
WP	12 ± 2 °C
Fe	12 ± 2 °C
Zn+Mn	12 ± 2 °C

500 grams of Filderlehm soil at 18% moisture contents with additional N, P, K and Mg fertilizer was filled in each rhizo-box

Root growth of maize seedlings at low RZT

4 weeks old maize seedlings grown in nutrient solution



UPI WP Fe Zn+Mn Control

12 °C 20 °C

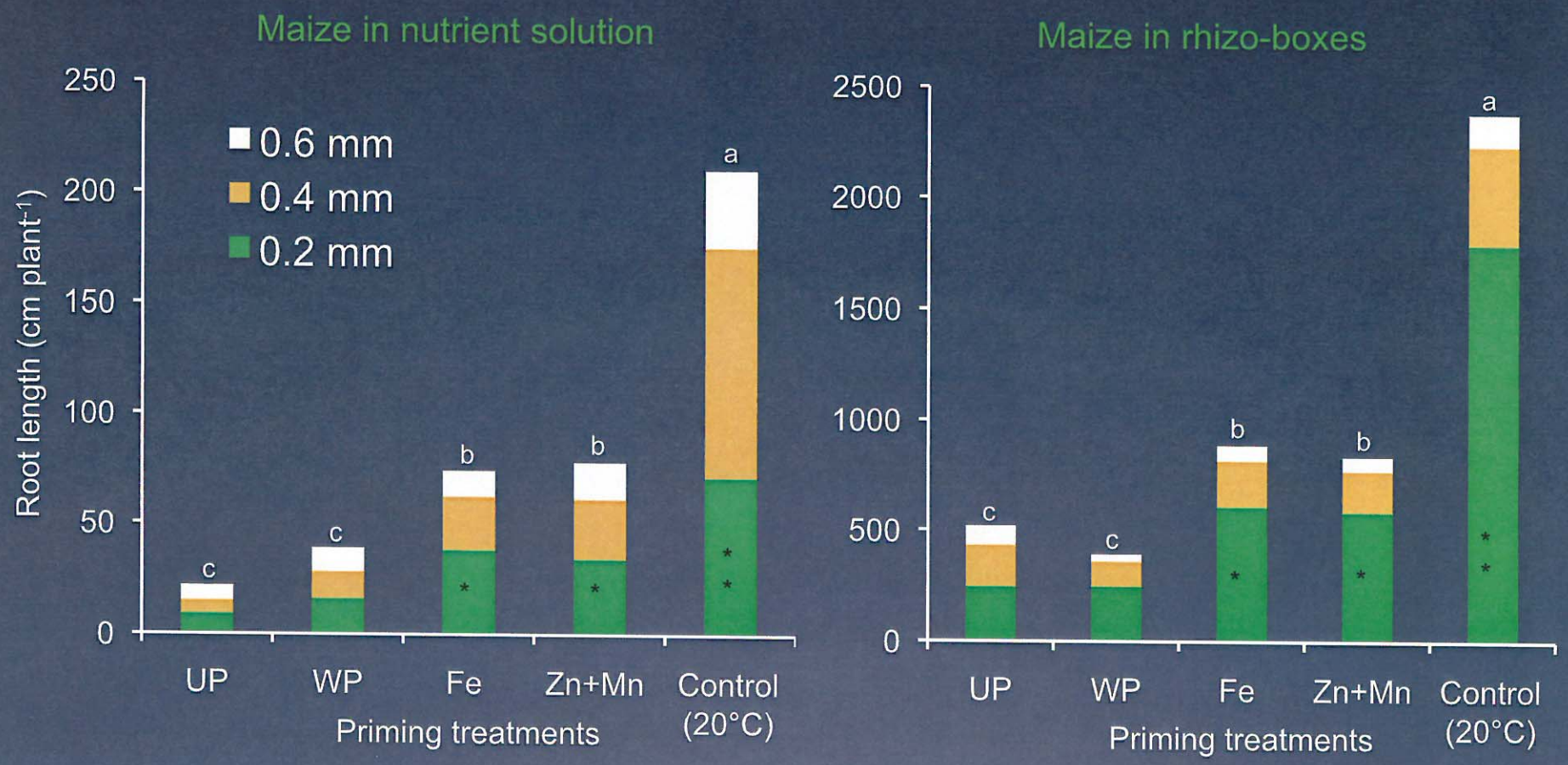
4 weeks old maize seedlings grown in soil culture

UP WP Fe Zn+Mn Control

12 °C 20 °C

Impact of seed fertification on maize root growth at low RZT

Root length (different diameter classes) of maize seedlings grown at low RZT



Increase in total root length and development of more fine roots indicate the positive role of micronutrient seed alleviating in alleviating the inhibition of root growth under low RZT

Plant nutrient status

Shoot micronutrient contents of maize seedlings developed at low RZT

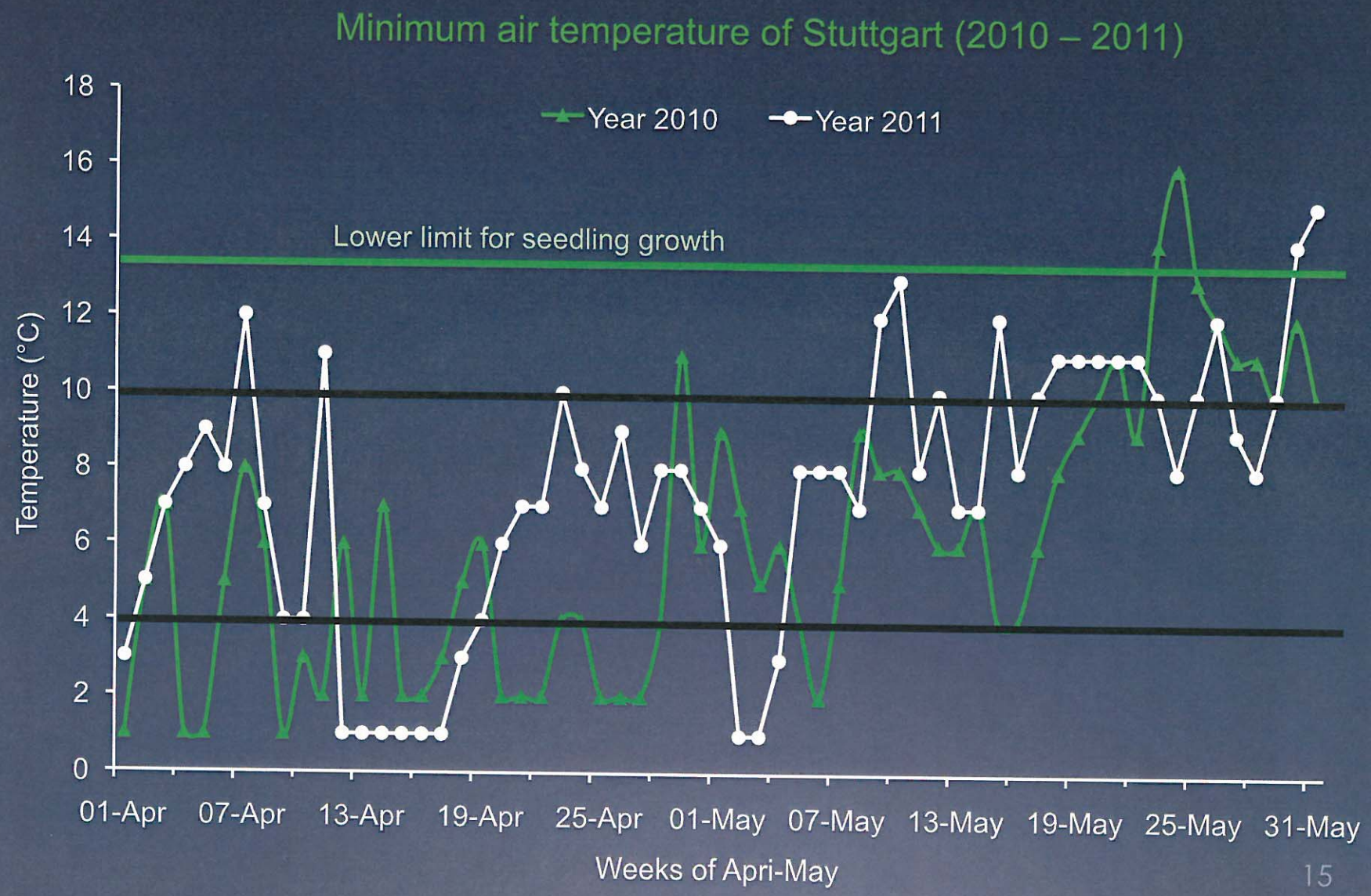
Experiment	Shoot nutrient contents (µg plant^{-1})					
	Nutrient solution			Rhizo-boxes		
Treatments	Zn (µg plant^{-1})	Mn (µg plant^{-1})	Fe (µg plant^{-1})	Zn (µg plant^{-1})	Mn (µg plant^{-1})	Fe (µg plant^{-1})
UP	7 ±1c	3 ±0c	13 ±1c	7 ±1c	12 ±2c	24 ±5c
Water	6 ±0c	4 ±0c	12 ±0c	8 ±1c	15 ±2c	26 ±4c
Iron	15 ±1b	11 ±1b	29 ±2b	13 ±1b	18 ±2b	37 ±1b
Zinc + Mn	13 ±1b	12 ±1b	30 ±2b	13 ±2b	23 ±2b	34 ±3b
Control (20°C)	42 ±4a	31 ±2a	38 ±2a	19 ±1a	45 ±2a	64 ±2a

Significant difference at $p < 0.05$

Micronutrient supply is limited during early seedling development under low RZT condition, which can be supplemented by seed fertification to improve plant nutrient status

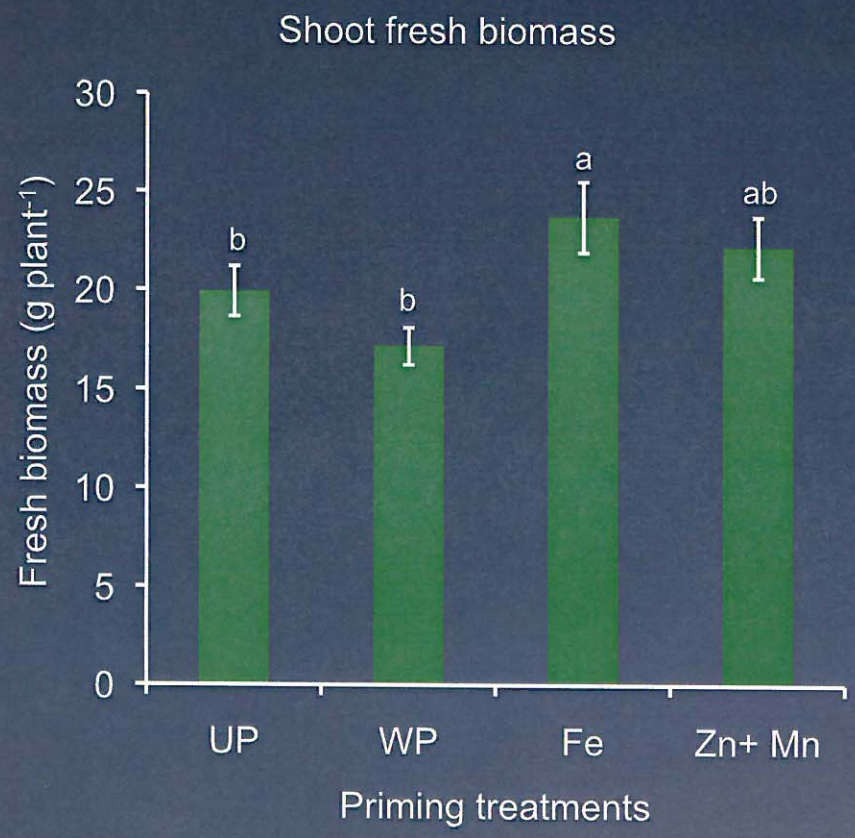
Field trial of fertified maize seeds

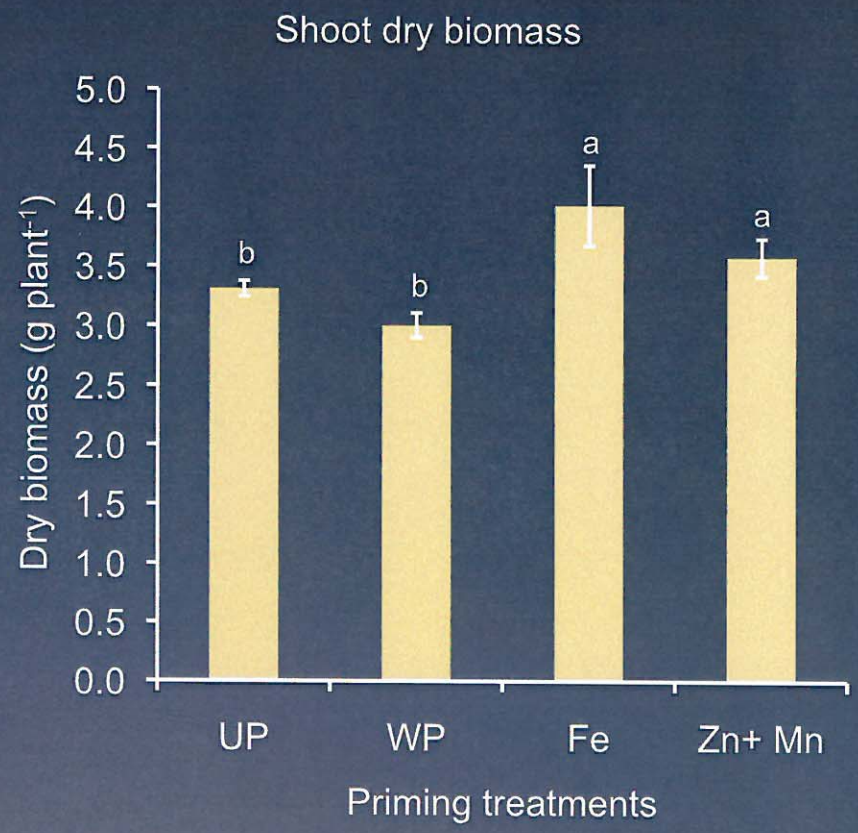
Low temperature is a major problem for maize seedling development at early spring in Central and Northern Europe



Growth of maize plants under field conditions

Shoot biomass accumulation in 5 weeks old maize plants grown under field conditions in year (2011)





Micronutrient seed fertification increased shoot biomass production of 5 weeks old maize plants grown in field conditions

Maize final grain yields in years 2010 and 2011

Treatments	Yield (kg ha^{-1}), 2010		Yield (kg ha^{-1}), 2011	
	Harvested yield	Marketable yield	Harvested yield	Marketable yield
UP	11026±341 b	7889±229 b	14267 ±145b	11670 ±110b
WP	11281±184 b	8059±135 b	15210 ±143b	12443 ±138b
Fe	12565±359 a	9021±293 a	15887 ±179a	13177 ±141a
Zn + Mn	12700±173 a	9083±164 a	16370 ±202a	13379 ±96a

Significant difference at $p < 0.05$

Harvested yield = fresh harvested grains from field

Marketable yield = grains yield with 12% moisture contents

Micronutrient seed fertification increased final grain yield by 10-15% in maize crop grown under field conditions.

Conclusion

Improved seed nutrient status is important for early plant growth and stress tolerance in crop plants.

Seed fertification is a suitable technique to improve seed nutrient contents.

In model experiments, improved early seedling growth and increased development of fine roots under low RZT conditions revealed that micronutrient seed fertification increase low RZT stress tolerance in maize.

Increase in final grain yield showed the persistence of seed fertification affects on maize crop under field condition.

It is necessary to have right concentrations and combinations of mineral nutrients for beneficial effects of seed fertification under different stress conditions

Result of miscalculation of nutrients leads to leaf deformation of soybean leaves

I am thankful to

Prof. Dr. Günter Neumann

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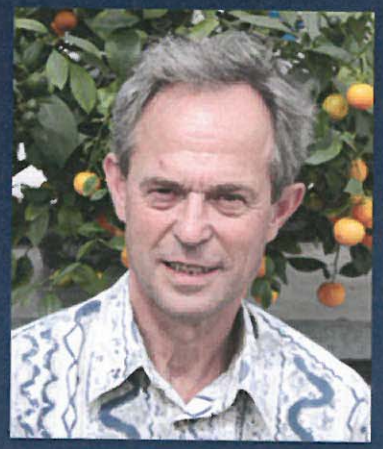

At present, after finishing my studies in Germany, I am living in Slagelse and looking for job to start my career in Denmark seed industry

Thank you