Yield starts with better seed nutrient density

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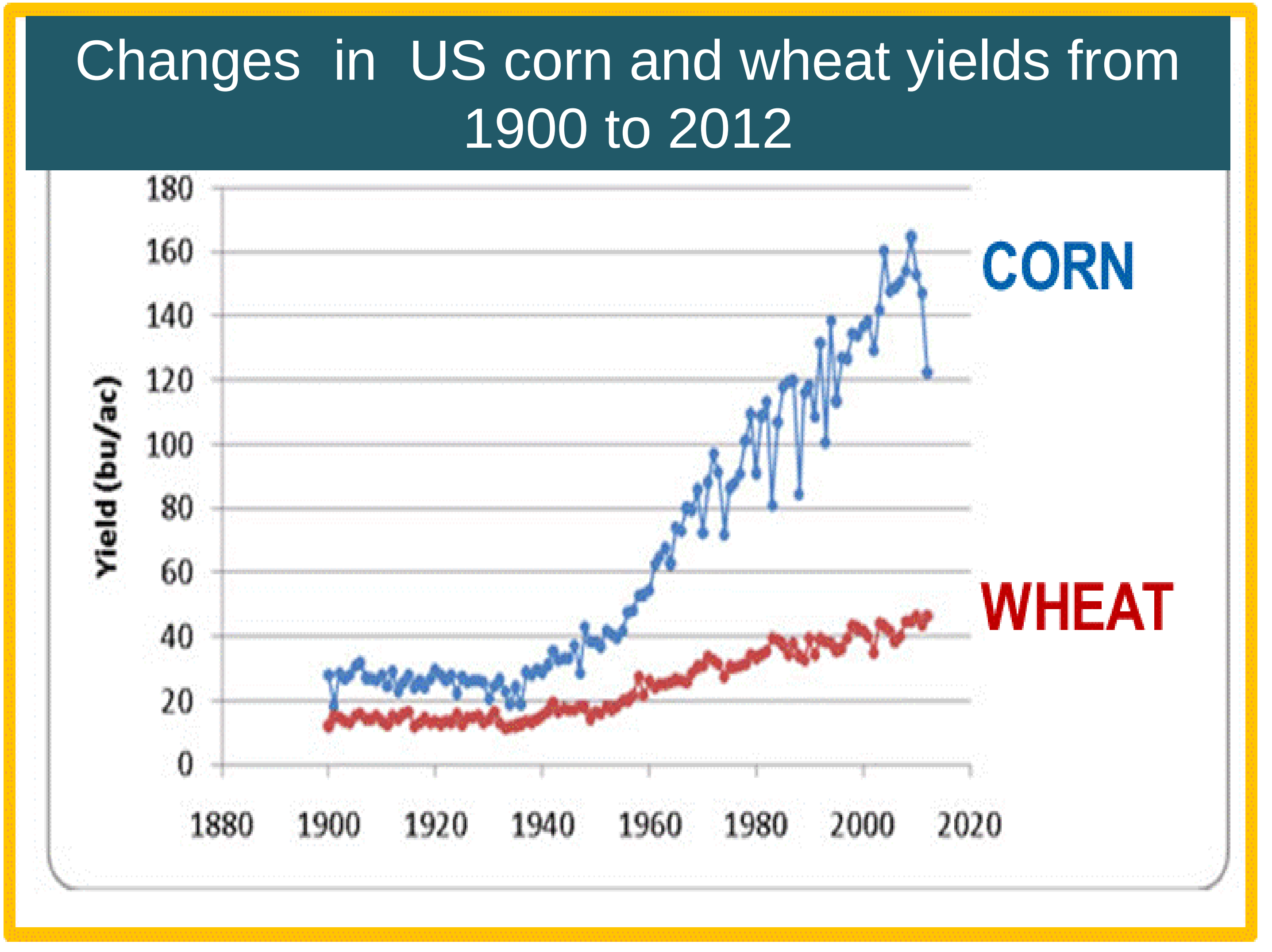
INTRODUCTION

Seed reserves of nutrients represent a key factor affecting positively 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 nutrient density.

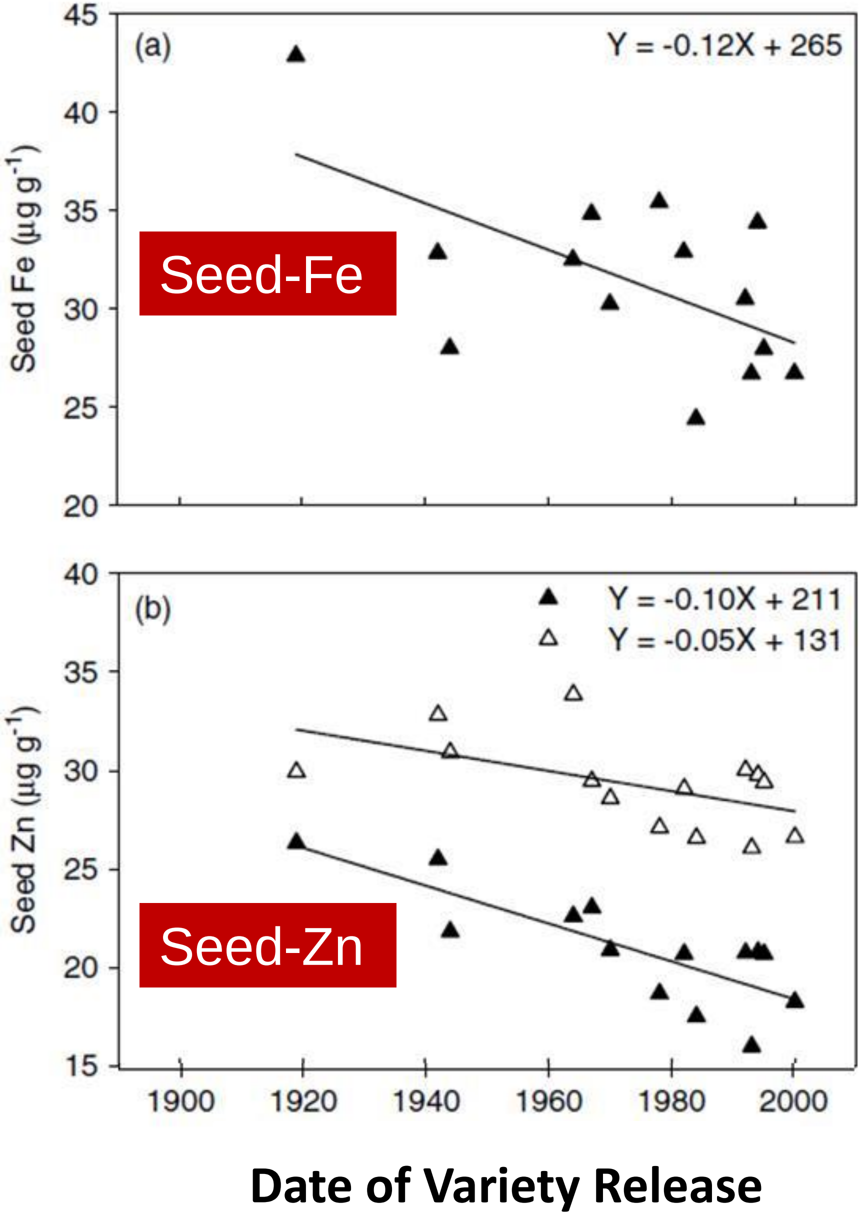
Today, little attention is, however, paid to the importance of **seed nutrient reserves** in practical agriculture

Increasing grain yield of new varieties results in large **dilution** of seed-nutrients

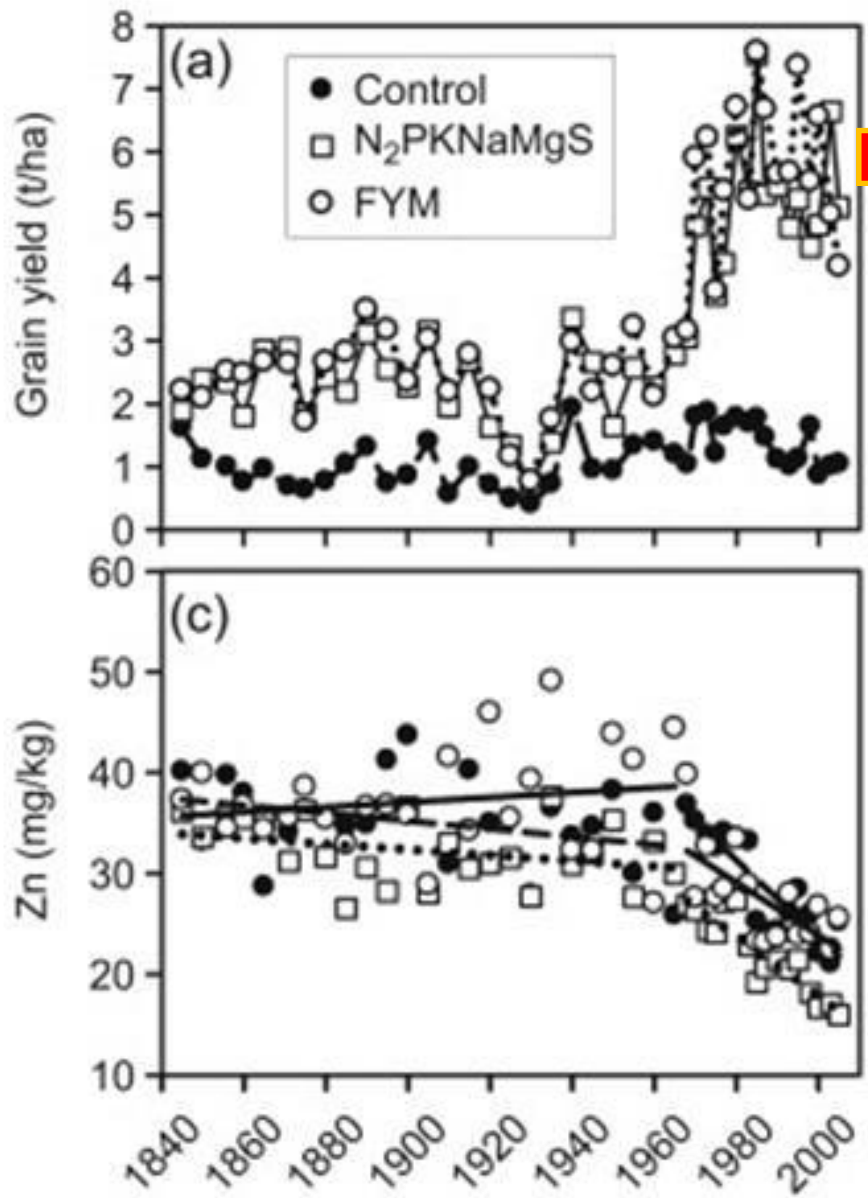


USDA and www.cato.org

Historical shifts in the seed Fe and Zn concentration of US wheat



Garvin et al. 2006, J Sci Food Agric 2213–2220



Years

Increase in grain yield

Changes in wheat grain yield and grain Zn concentrations in wheat grown in Rothamsted-UK since 1845.

Decline in grain zinc

Fan et al. 2008, Trace Elem Med Biol

Dilution of nutrients in seeds has adverse consequences both

i) for human nutrition (e.g., malnutrition problem in human populations consuming predominantly cereal-based diet) and also

ii) for the seed quality-vitality for germination

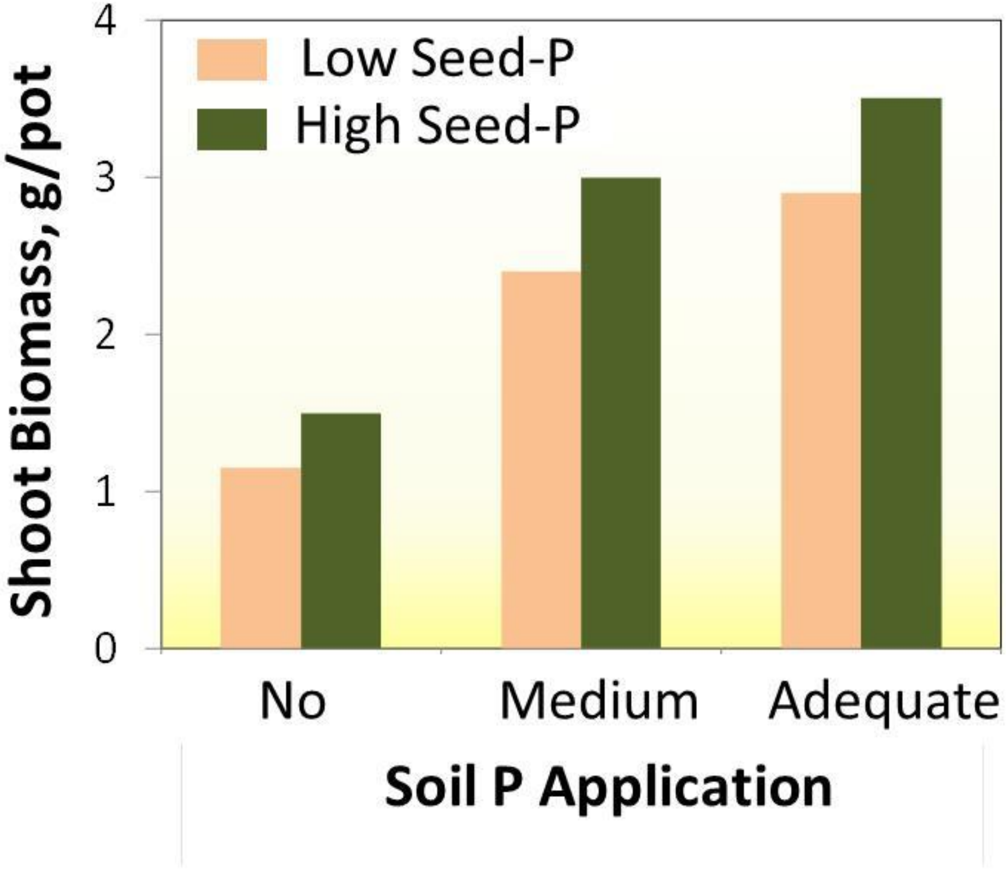
Published reports indicate that plants need most of their total P (up to 75 %) during their early growth stage.

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).

These findings highlight importance of seed P-reserves

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

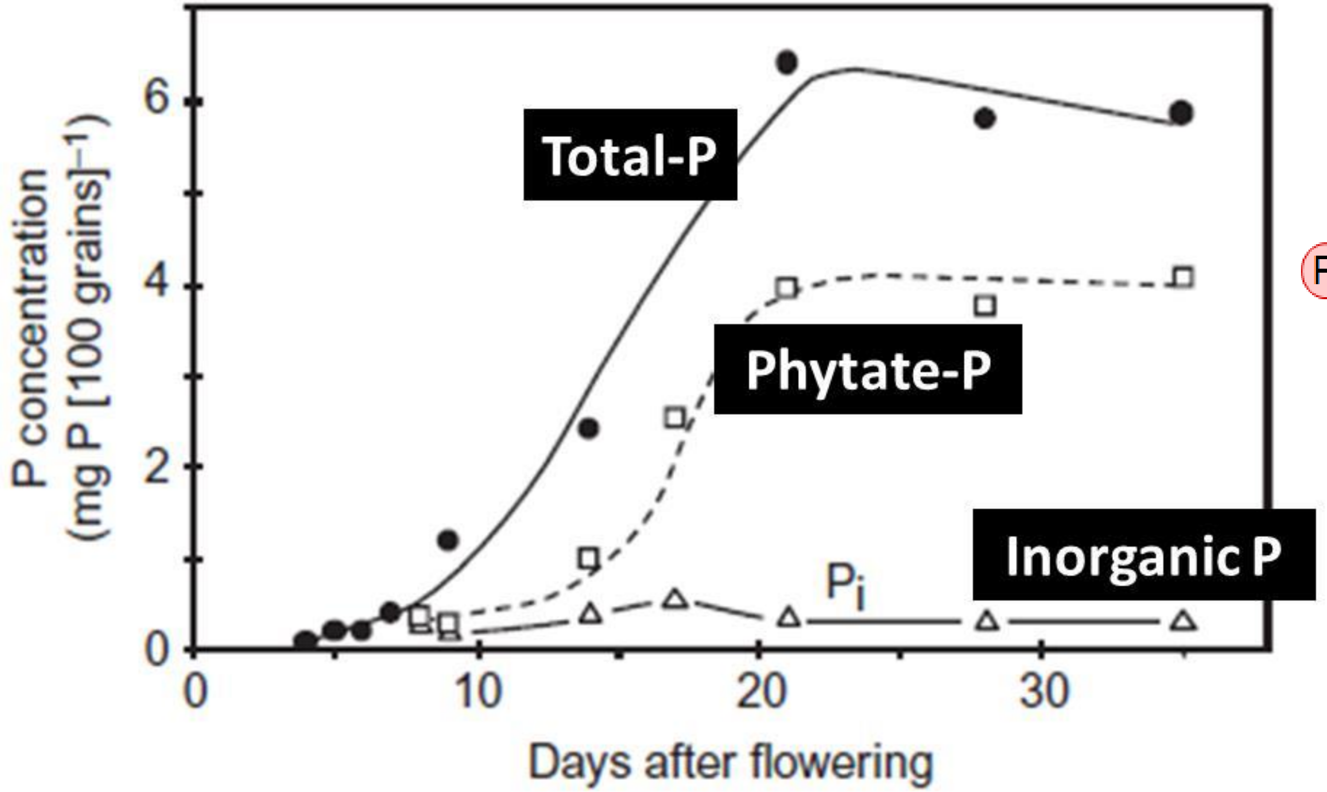
(**Low-P seed**: 98 µg/seed; **High-P seed**: 213 µg/seed)

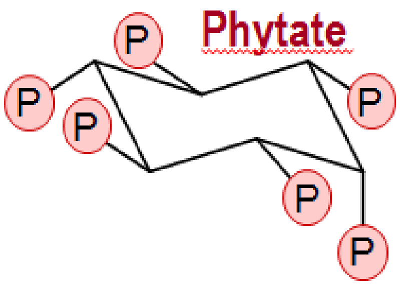


Even, at adequate P supply, use of seeds with high P is needed in achieving better growth

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

Total-P, phytate-P and Pi concentration in rice grains during grain development.





Phytate is the typical storage form of P in seeds/ grains

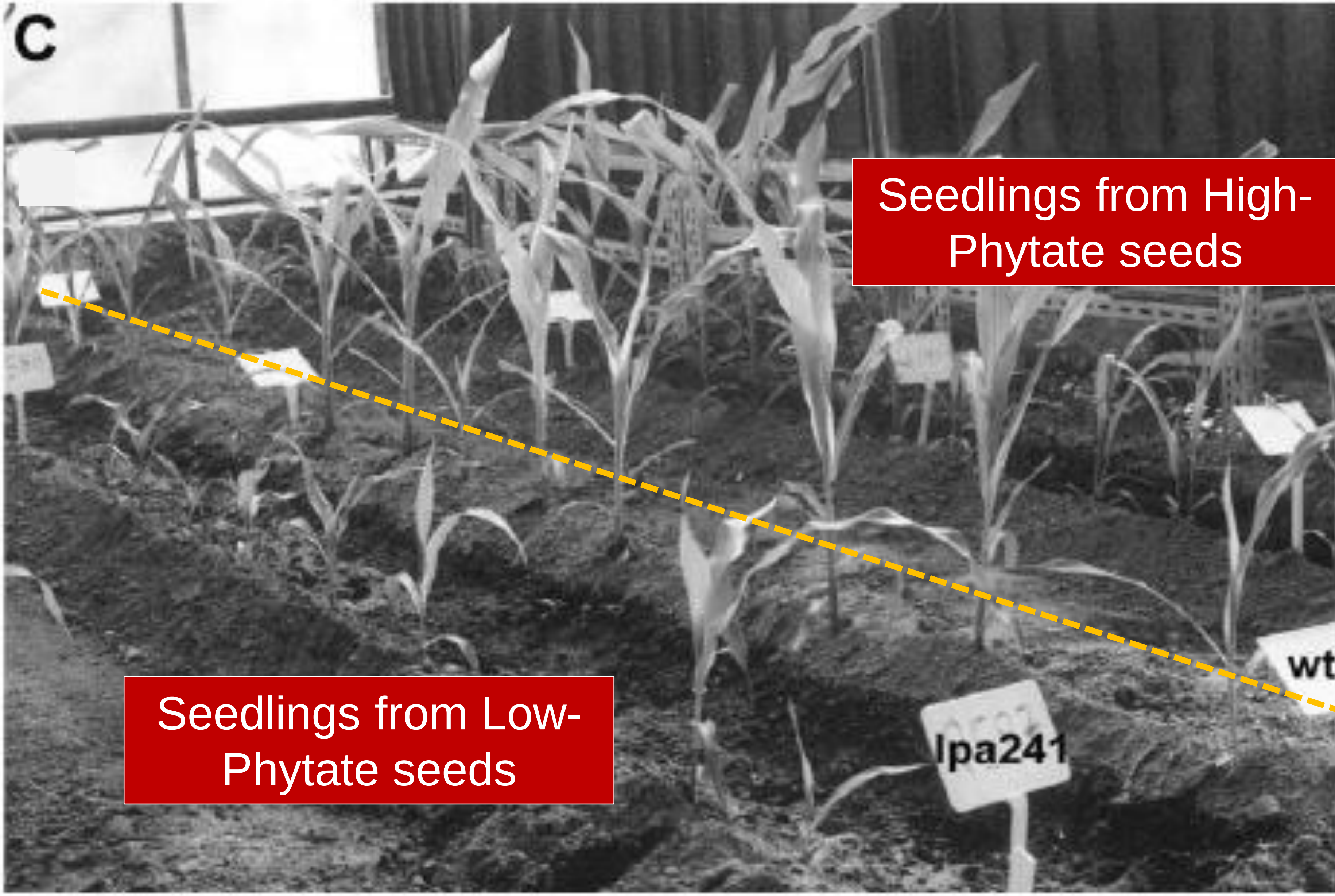
Marschner, 2012

Phosphorus fractions in rice seeds during germination

Duration of germination (h)	P fraction (mg P g^{-1} dw)		
	Phytate	Lipid	Inorganic -P
0	2.67	0.43	0.24
24	1.48	1.19	0.64
48	10.6	1.54	0.89
72	0.80	1.71	0.86

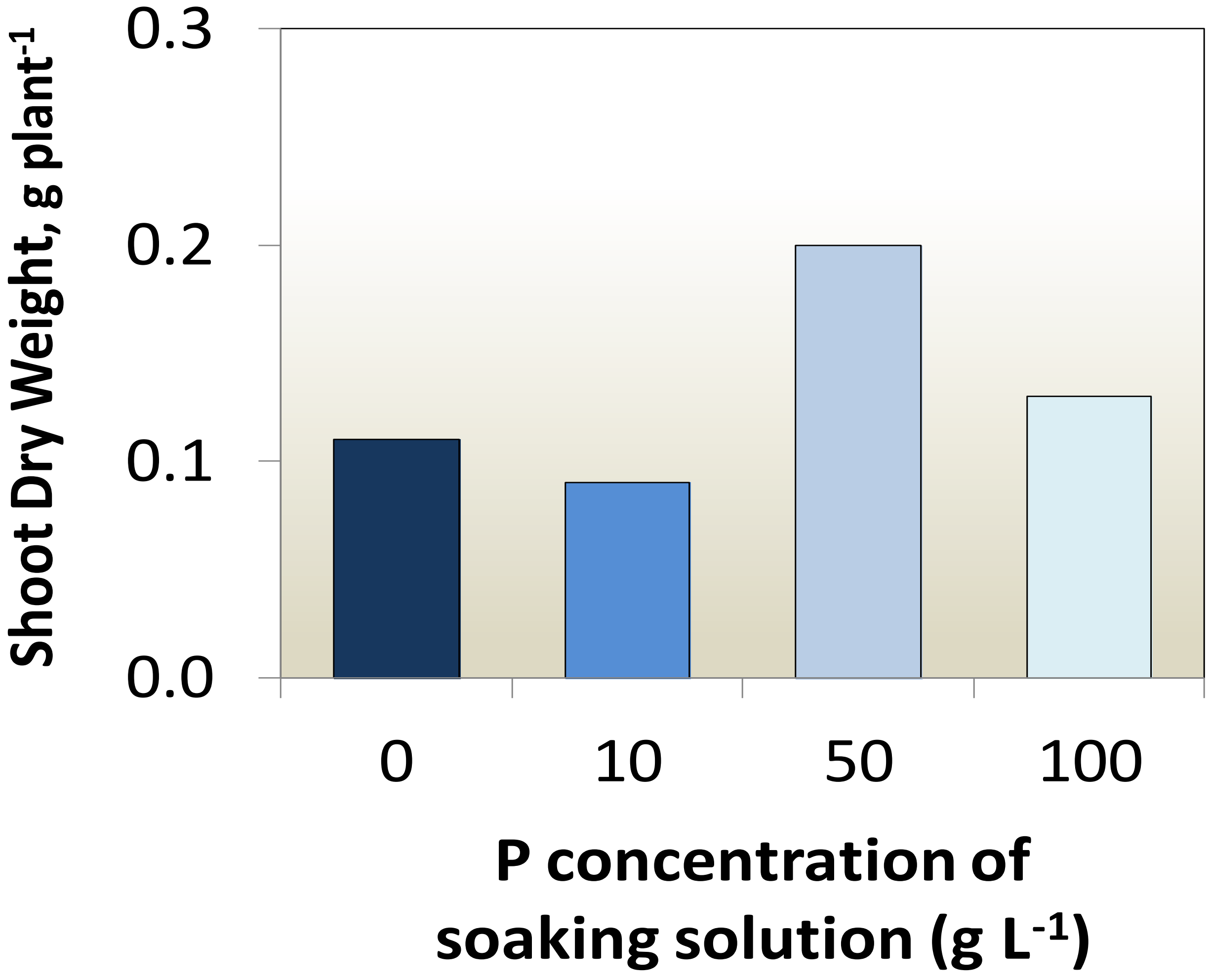
The function of phytate is to provide the germinating seedling with a source of P for synthesis of membrane lipids and nucleic acids.

Marschner, 2012



Oltmans et al., Crop Sci. 45:593-598, 2005

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

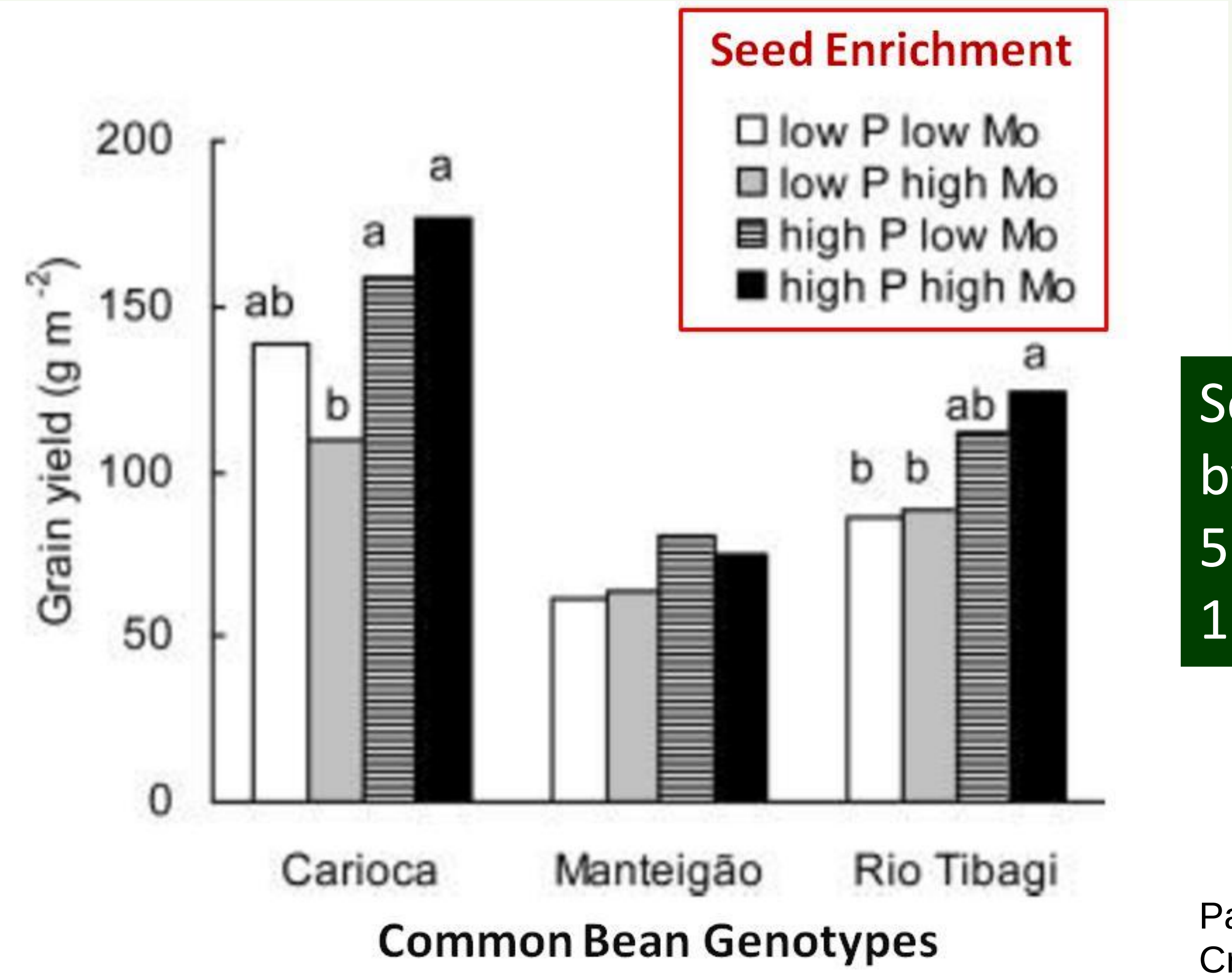
Legume plants depending on biological N_2 fixation for their N supply require more P and Mo than plants receiving fertilizer N, since the reduction of atmospheric N_2 by the nitrogenase system is a very energy-consuming process, and more Mo and P are needed for symbiotic N fixation than for general plant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

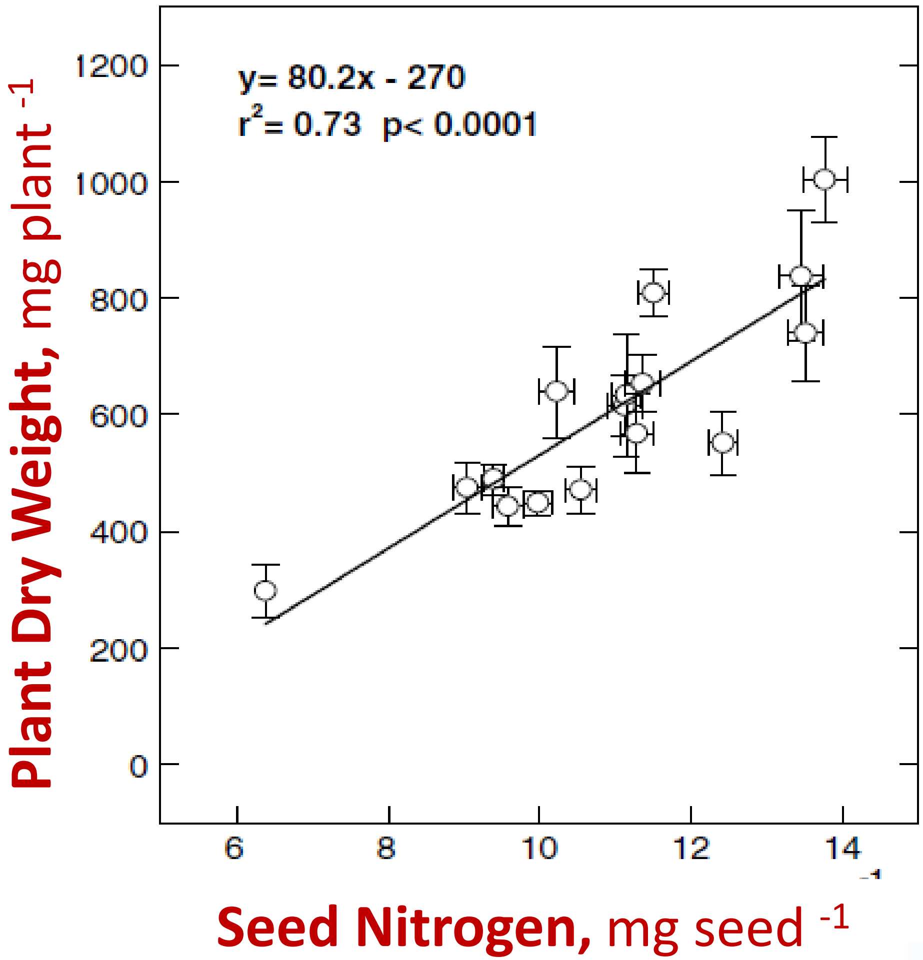
N Deficiency in Legume Seedlings and Seed N Reserves

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

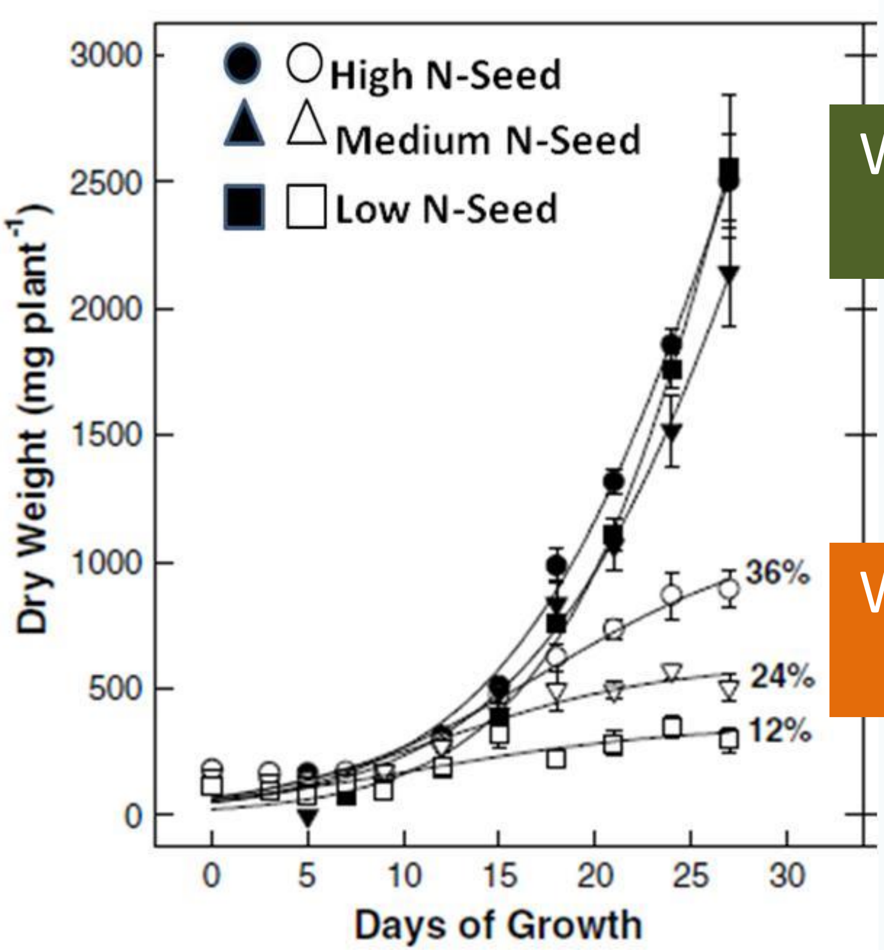


Seed N and Seedling Growth

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 %

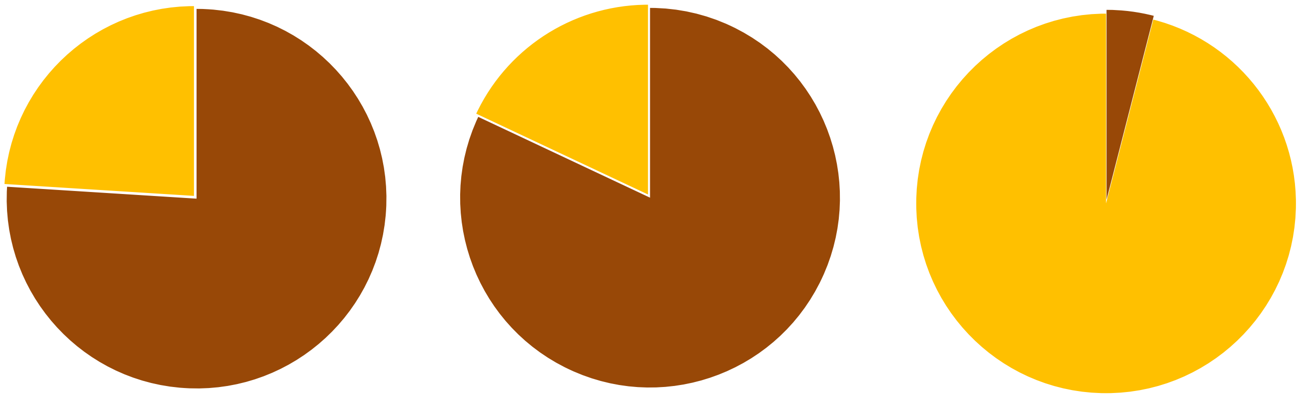


When N supply is adequate

When N supply is inadequate

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

Distribution of nitrogen, phosphorus, and calcium in pea seeds
(% of total shoot content)

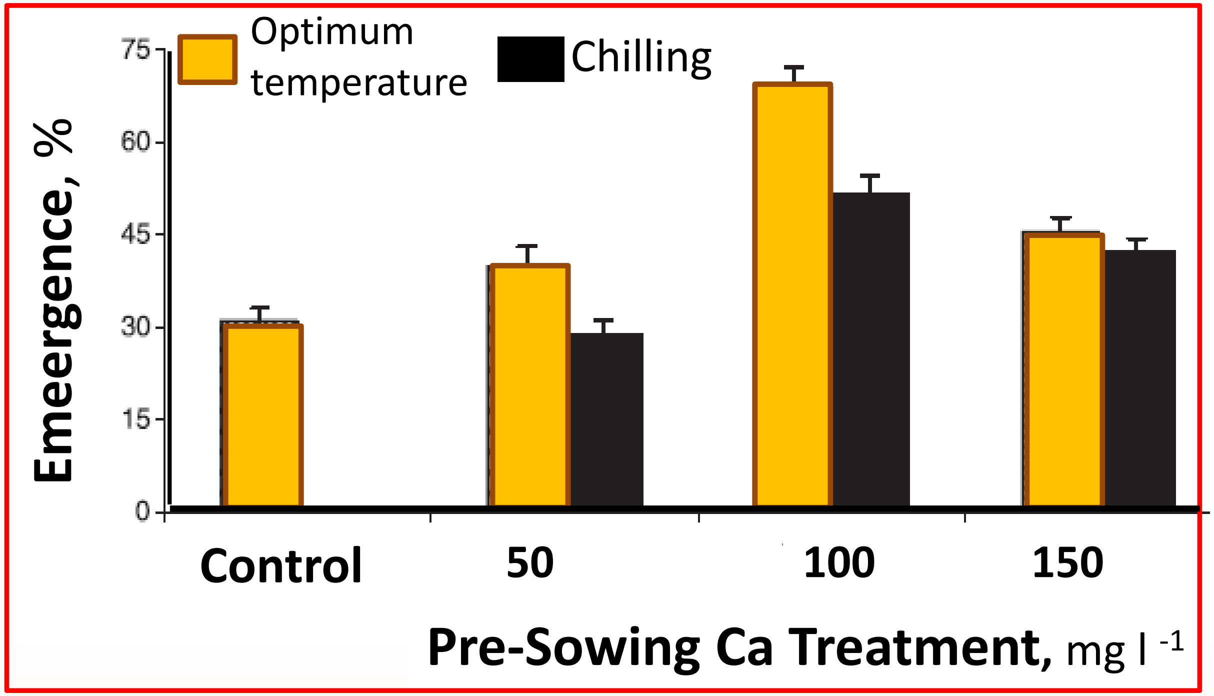


	Nitrogen	Phosphorus	Calcium
%	76	82	4

Ca is not mobile in plants. Seeds are very low in Ca

Redrawn from from Marschner, 2012

Influence of pre-sowing $CaCl_2$ seed treatments on germination of maize under normal and low temperature (15 °C) stress

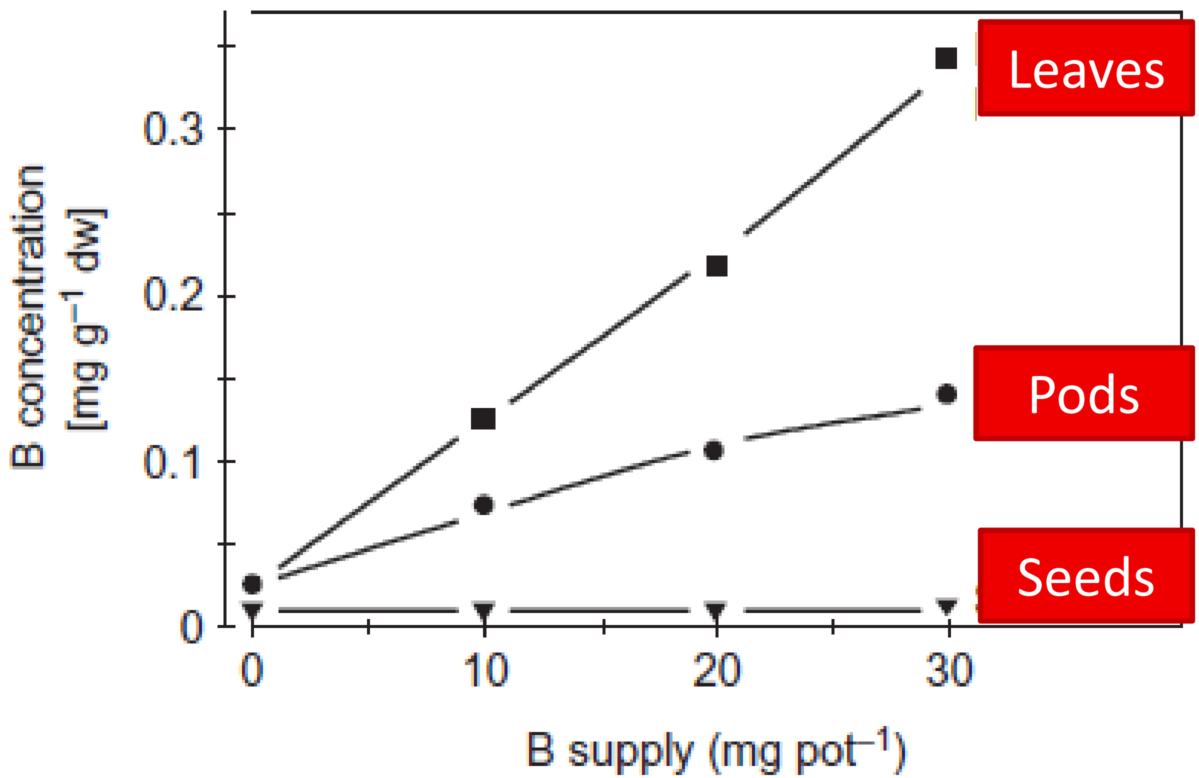


Farooq et al., 2008, J. Agron. Crop Sci

Micronutrients are also important for better seed vitality, seed germination and better seedling vigour

Seed-Boron

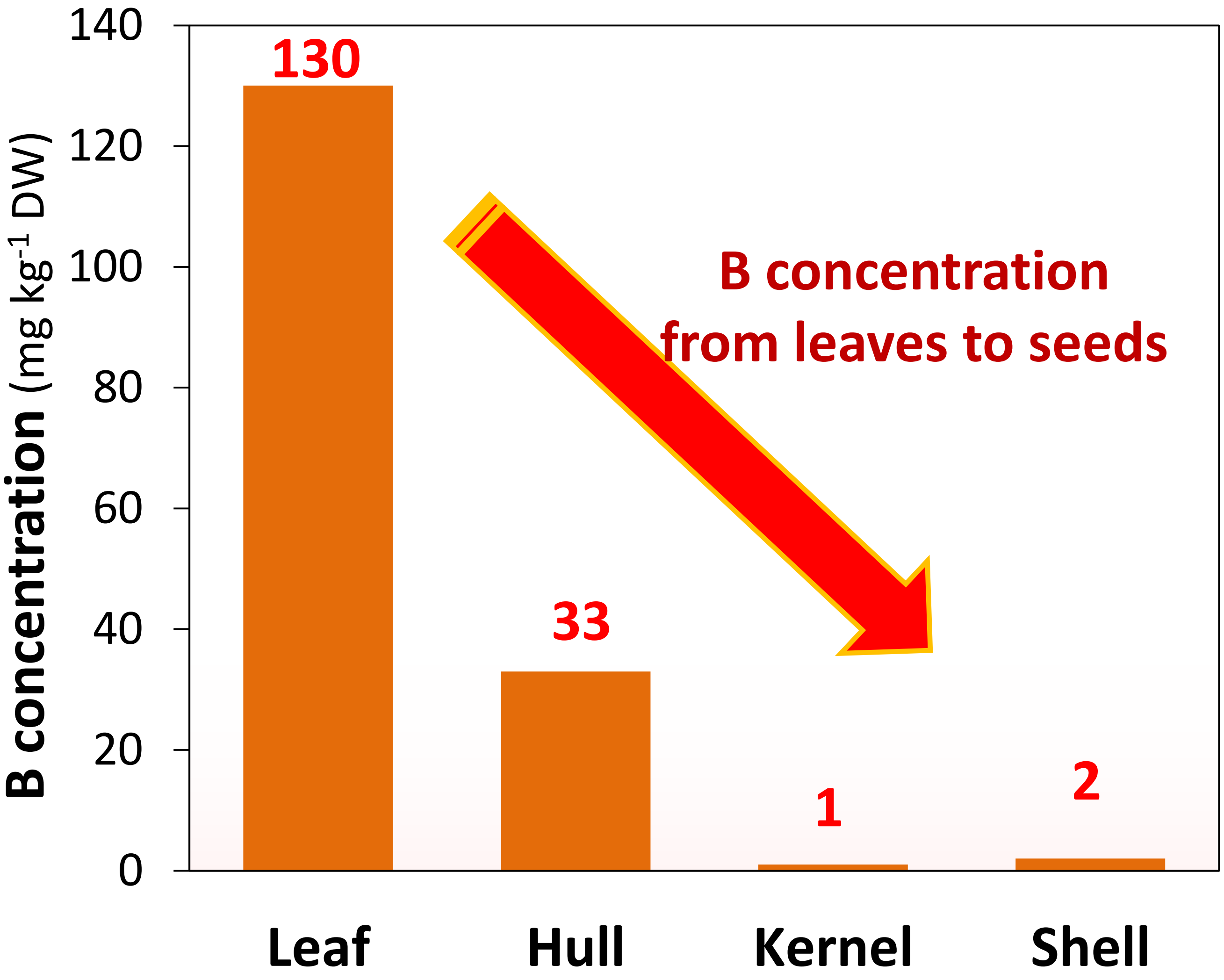
Distribution of B within the shoot of canola with increasing B application to the soil.



Boron is also immobile in most of the plants.
Seeds are very low in B

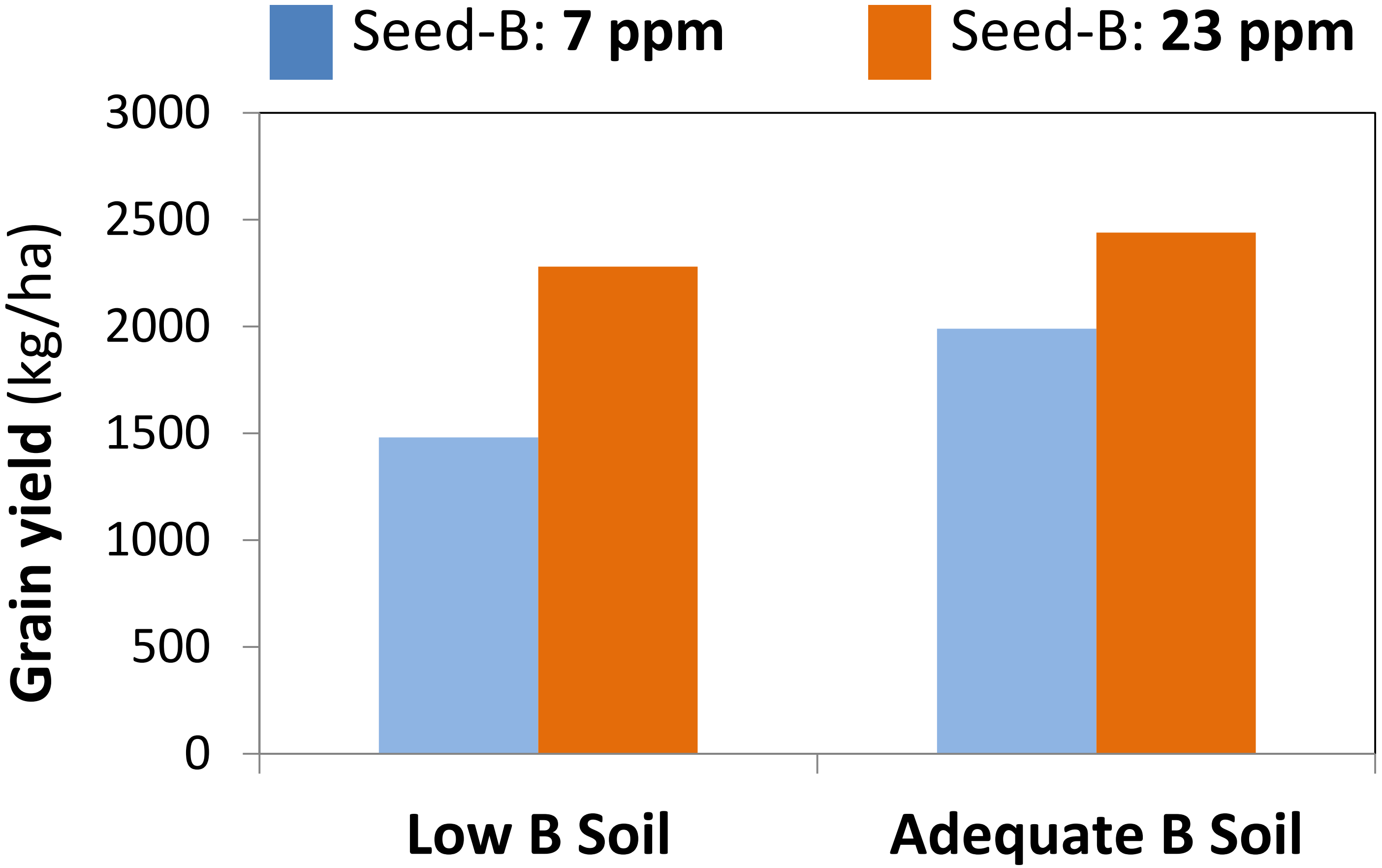
Marschner , 2012

Changes in boron concentration in different shoot organs of pistachio



Brown and Shelp, 1997

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

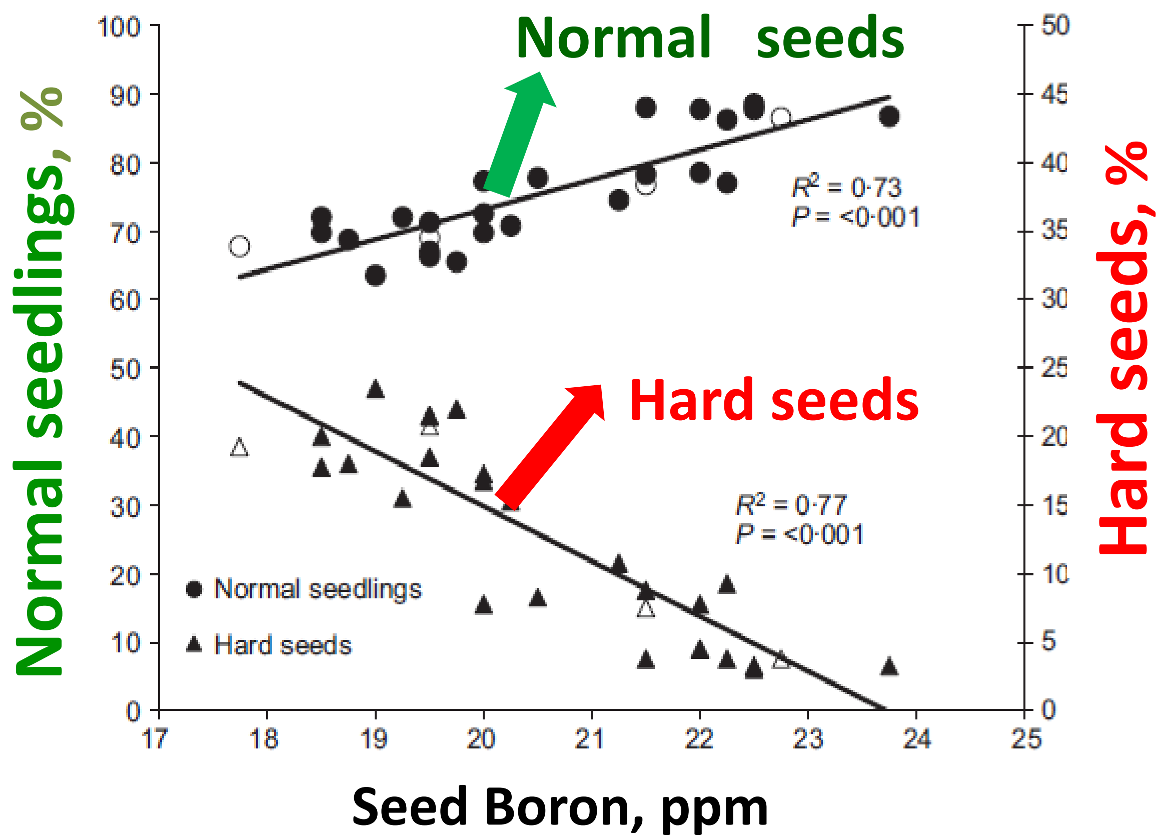


Rerkasem et al., 1997, Nutr. Cyc. Agroecosystems, 48: 217-223

Soybean seeds with 10 mg B kg^{-1} have deformed cotyledons, **performed poorly and had permanently damaged seed embryos**, preventing their germination adequately.

The critical concentration of B in soybean seed for normal seedling development in low B soils sdeem to be between 15 and 20 ppm

Relationship between the seed B concentration and seed viability (with normal and poor germination hard seeds) in red clover (means of four field experiments)



Stoltz and Wallenhammar, 2013; Grass and Forage Sci.

A hard seed is a seed that does not swell or germinate within its established period of viability.

Seed-Zinc

Zinc Localization in Germinating Wheat Seed

(Red color)

Staining Zn

Zn Concentrations: mg Zn kg^{-1}

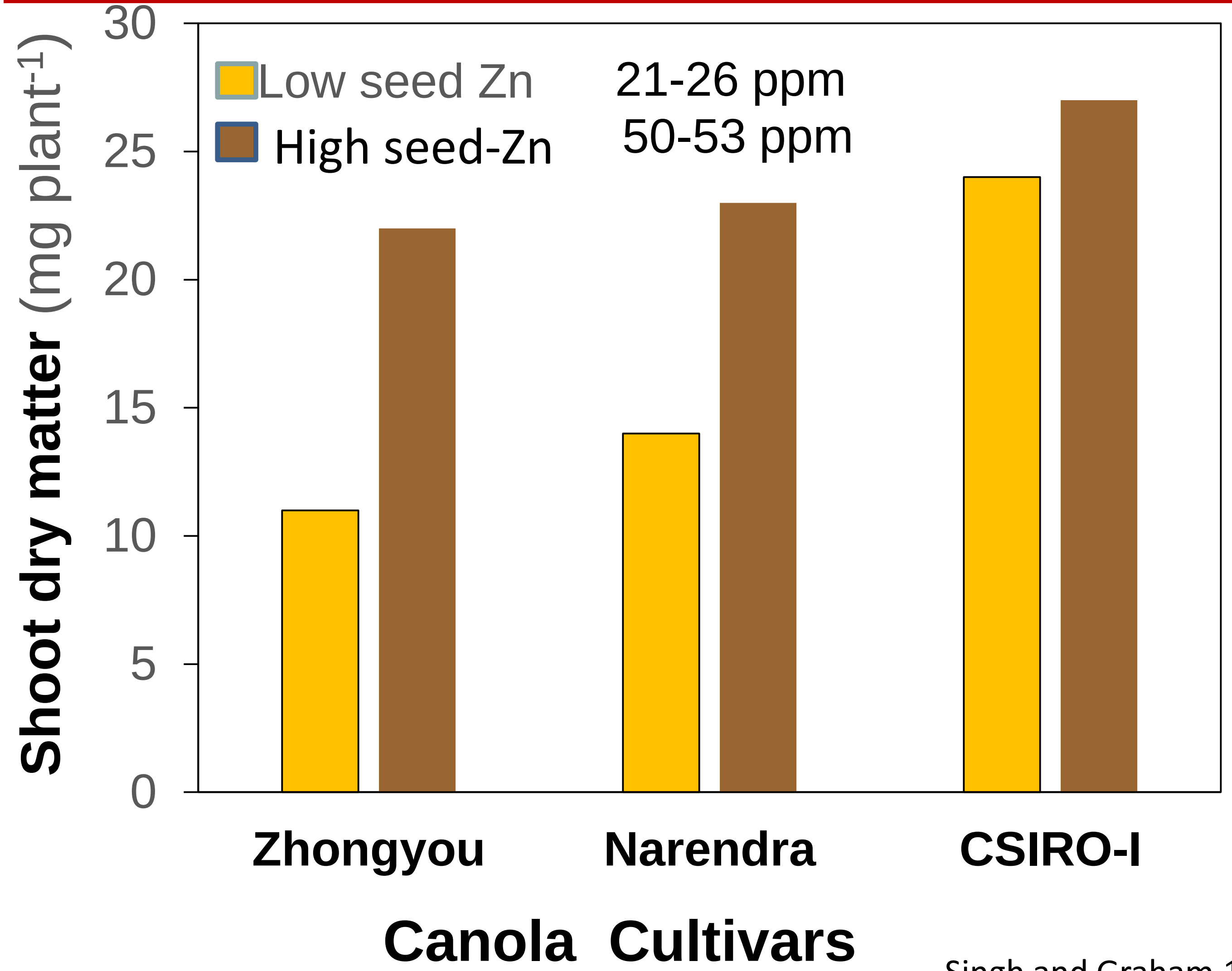
Parts emerging from seeds need very high Zn

Ozturk et al., 2006, Physiol. Plant. 128:144-152

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 seed germination and seedling development.

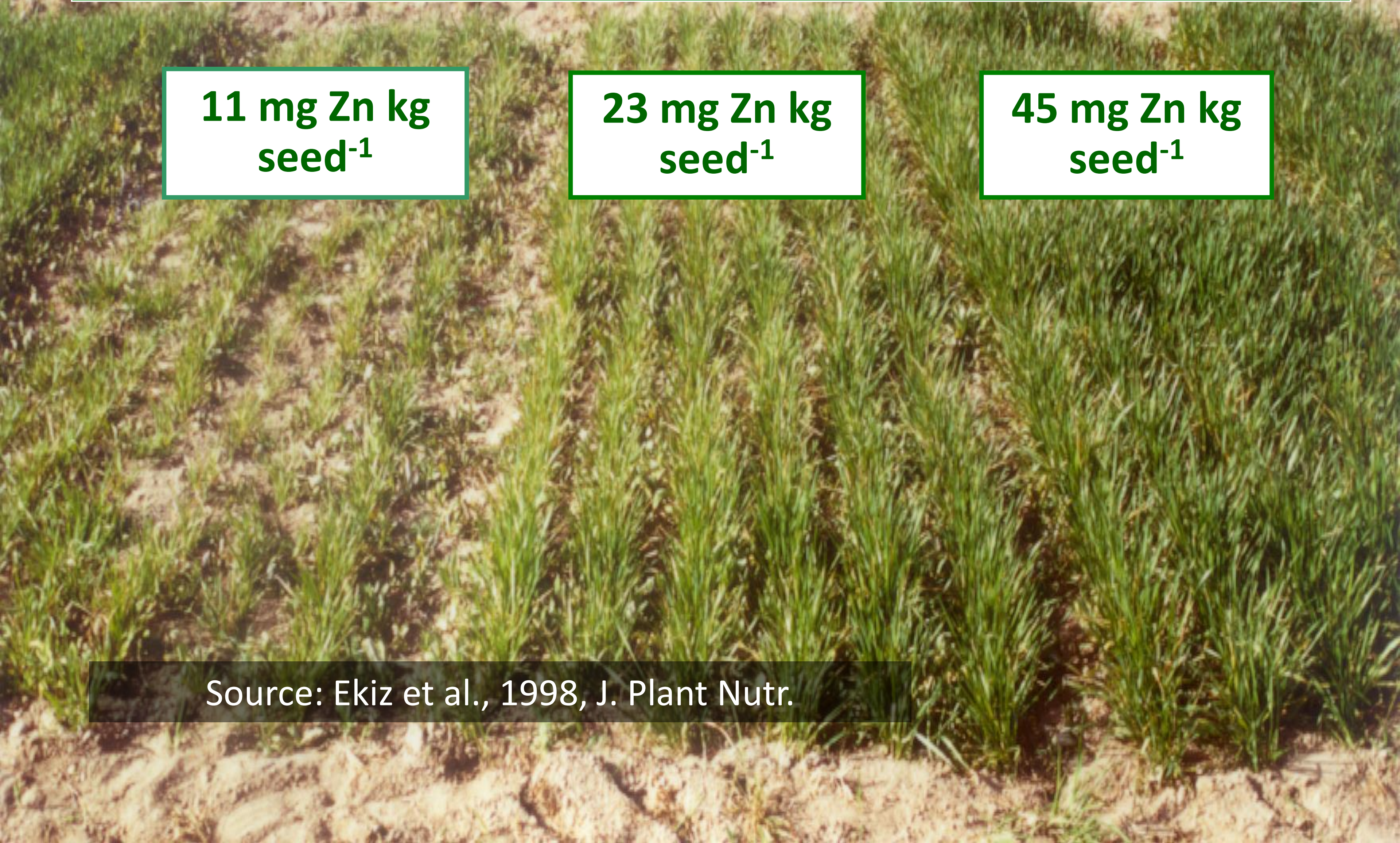
High seed Zn in seeds acts as a “**starter Zn fertilizer**”

Shoot dry matter production of 3 canola cultivars with low and high seed Zn

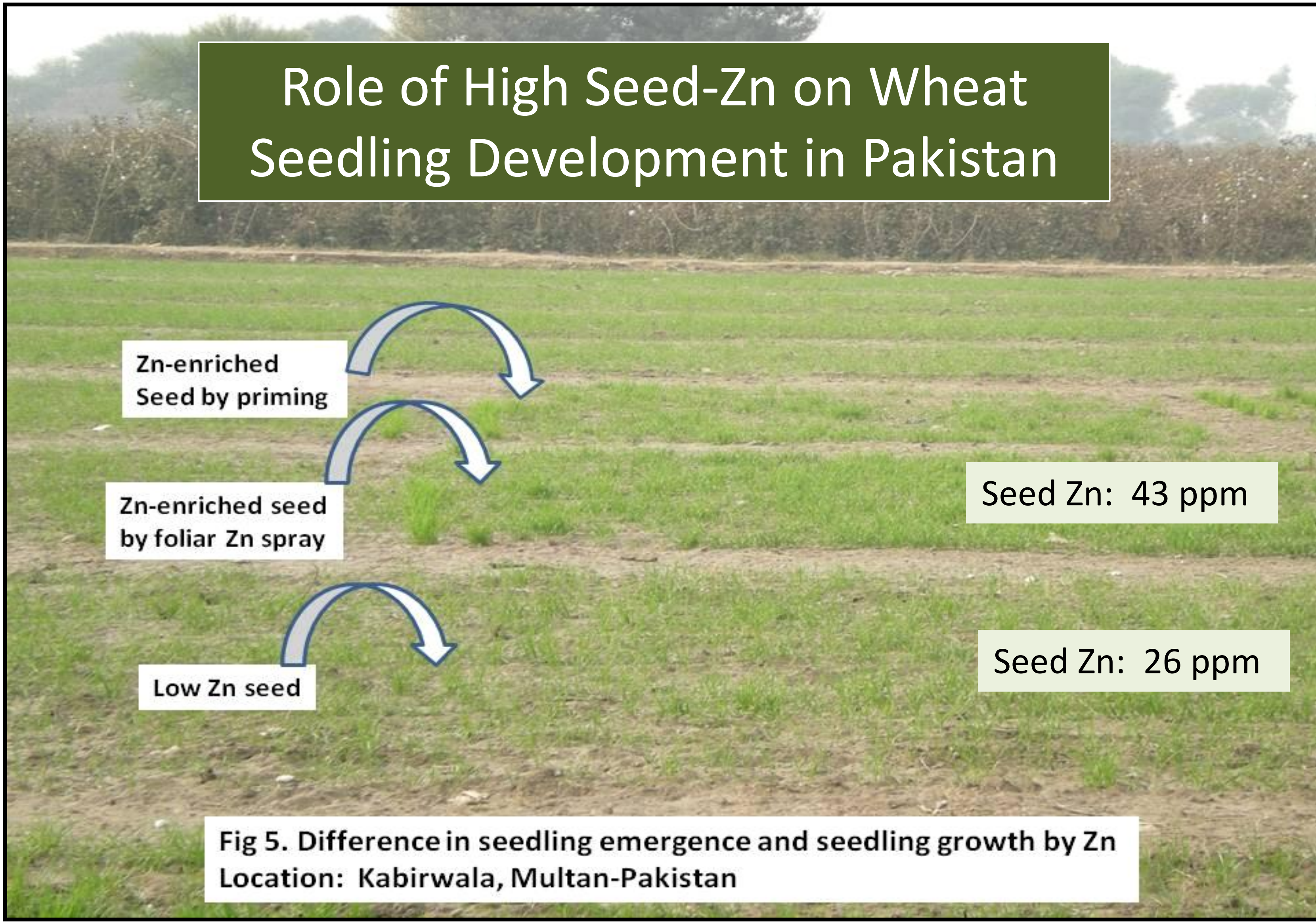


Singh and Graham,1997, Plant and Soil, 192: 191-197

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

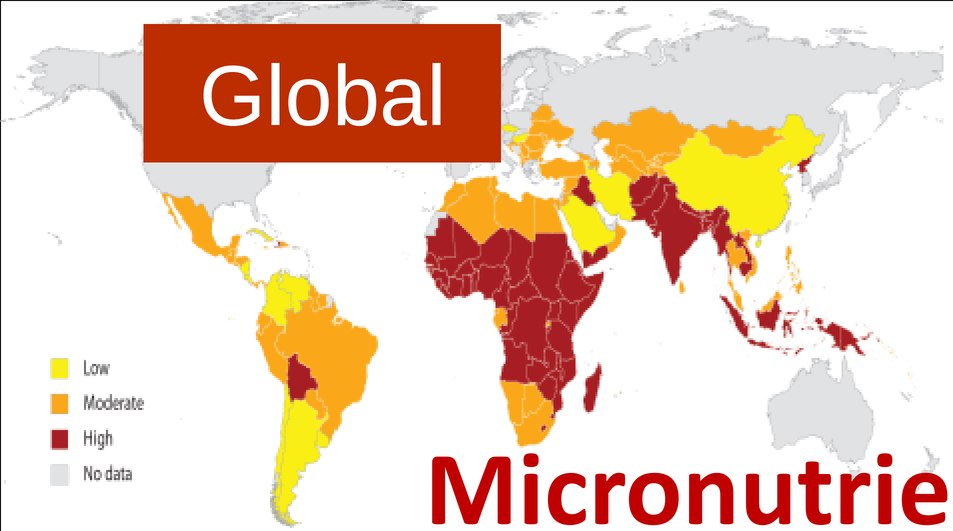


Source: Ekiz et al., 1998, J. Plant Nutr.



Picture: A. Rashid et al. 2012

Global

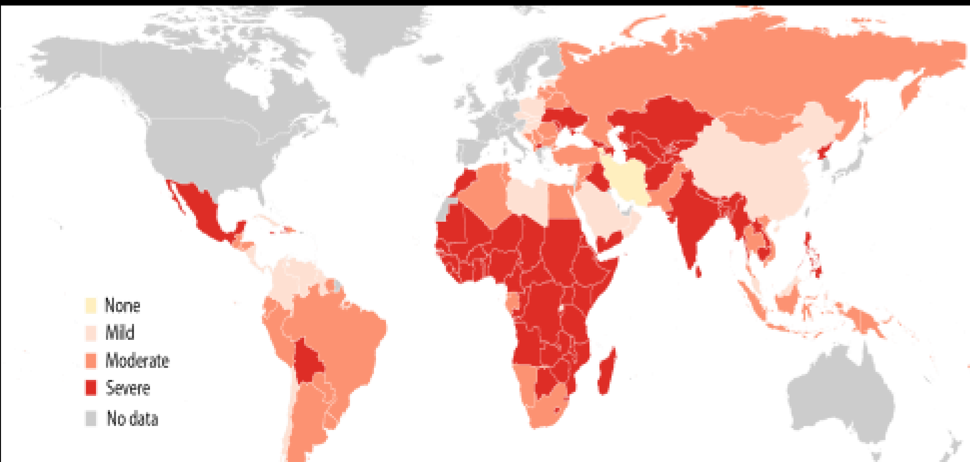


Zinc

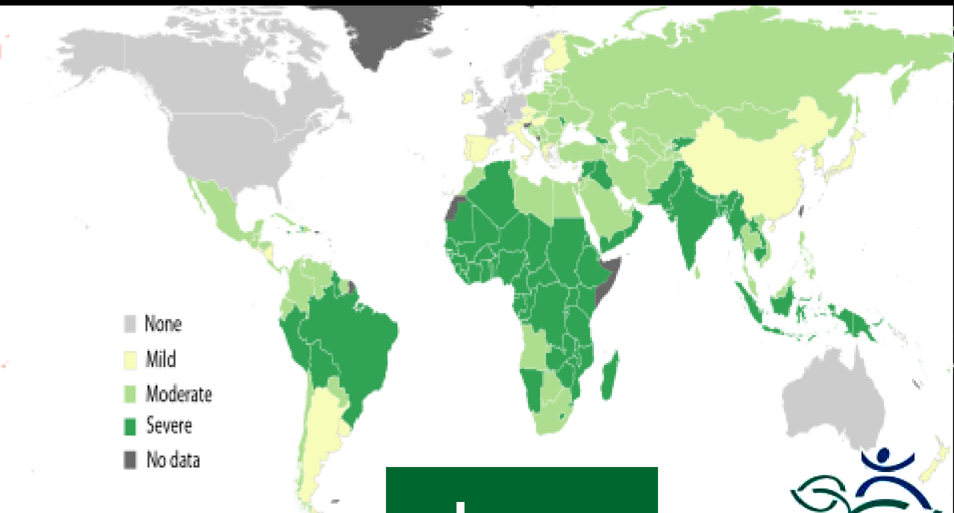
Micronutrient Deficiency

(World Health Organization)

More than 2 billion people affected globally by micronutrient deficiencies…the hidden hunger



Vitamin A



Iron

HarvestPlus
Breeding Crops for Better Nutrition

Conclusions

Seeds with higher nutrient density exhibit better field establishment, produce more vigorous seedlings and finally contribute greatly to final yield

Avoiding nutrient deficiencies on maternal plants during late growth stage, is important not only for better yield but also for better nutrient density and seed viability

Soil and foliar fertilization practices should also include the aspects of seed nutrition (**seed fertilization**).

Thanks…