

Relationships between Zinc and Other Nutrients in Wheat Grain

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INTRODUCTION

There is much interest in improving the grain nutrient density of wheat to improve the delivery of essential mineral nutrients in human diets. Genotypic differences in grain-Zn concentration occur (Graham et al. 1999), but our understanding of the reasons for these differences is incomplete. Many studies that have examined differences in grain-Zn do not consider variation in other nutrients. Correlations between grain-Zn concentrations and other nutrients may reflect for example, similar nutrient sinks or similarities in transport mechanisms. If relationships within the nutrient profiles are consistent across environments, it may provide some insight into the bases of genotypic differences in grain. We examined nutrient profiles in bread and durum wheat from field and glasshouse experiments to test this concept.

METHODS

Grain of bread wheat (*Triticum aestivum*) was obtained from replicated field trials that compared the Zn response among a range of well adapted bread wheat varieties over 4 years. Each variety was grown at two levels of Zn, nil applied Zn and 7.6 kg Zn ha⁻¹ applied as Zn at sowing and supplemented with two foliar sprays of Zn. Grain samples were also obtained from a range of durum wheat (*T. turgidum*) accessions and primary synthetic hexaploid wheat lines grown under non-limiting conditions in the glasshouse. Whole grain samples were analysed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) after digestion in nitric acid. Relationships between the nutrients were examined by simple linear correlations and by Principal Component Analysis.

RESULTS AND DISCUSSION

Grain Zn concentration was independent of kernel weight (Table 1, Fig 1) indicating that high Zn concentration among the genotypes was not caused by nutrient concentration effects. However, grain yield was often correlated with grain Zn concentration but not consistently, with both positive and negative correlations evident. Grain Zn was correlated with Fe, P, Mg and S (Table 1, Fig 1). Positive correlations between grain Fe and Zn have been reported previously (Graham et al. 1999, Garvin et al. 2006) and may reflect common transport mechanisms to the grain. Phosphorus and Mg in the grain are mainly found in phytate, and their consistent correlation with Zn suggests that high grain-Zn may be associated with high phytate in wheat, as occurs in rice (Graham et al. 1999). The influence of S nutrition on grain-Zn has received little attention, but Zn can interact with cysteine because of its ability to bind with sulphhydryl ligands. In beans, the albumin fraction contained the highest concentrations of Zn (and Fe) but this protein fraction also contained the highest cysteine content, which strongly bound the Zn (Lombardi-Boccia et al. 1999). Glutathione, which transports reduced S in the phloem, also forms complexes with Zn. There are some reports of interactions between Zn nutrition and methionine. Faridi et al. (1982) [cited in Graham et al. 1999] found adding Zn increased methionine in wheat grain. Sulphur nutrition also influences the level of methionine, which is a precursor of nicotianamine and which is involved in phloem transport of Zn and Fe (Welch 1995). The correlation between S and Zn may reflect the S status of a genotype and its influence on nicotianamine production and transport to the grain.

Table 1. Mean grain yield (t ha⁻¹), range in grain-Zn concentration (mg g⁻¹) and simple correlations between grain-Zn and other nutrients among advanced lines of bread wheat. *-P<0.05. **-P<0.01, *-P<0.001; n.d.-not determined.**

	Year 1 (n=39)		Year 2 (n=42)		Year 3 (n=28)		Year 4 (n=36)	
	Nil	+Zn	Nil	+Zn	Nil	+Zn	Nil	+Zn
Grain yield	0.97	1.21	2.94	3.31	2.17	2.39	2.91	2.97
Grain Zn	9.7- 13.3	20- 31.0	9.1- 11.8	20.0- 31.0	9.7- 16.1	12.4- 19.4	8.7- 11.1	24.3- 34.0
Yield	-0.32	-0.53***	0.01	-0.57***	0.48**	0.14	-0.11	-0.16
Kernel wt.	n.d.	n.d.	0.23	-0.08	-0.11	0.04	-0.14	-0.15
Fe	0.55***	0.65***	0.37*	0.18	0.20	0.32	-0.15	0.40*
Cu	0.22	0.45**	0.20	0.05	-0.10	0.19	-0.12	0.29
Mn	0.41**	0.39*	0.03	0.12	-0.08	0.05	-0.17	0.18
K	0.04	-0.12	-0.01	-0.07	0.03	0.06	0.09	-0.19
Mg	0.41**	0.54***	0.36*	0.70***	-0.30	0.27	-0.06	0.46**
P	0.64***	0.63***	0.51***	0.49**	0.05	0.32	0.28	0.37*
S	0.54***	0.73***	0.35*	0.42**	0.05	0.27	0.25	0.67***

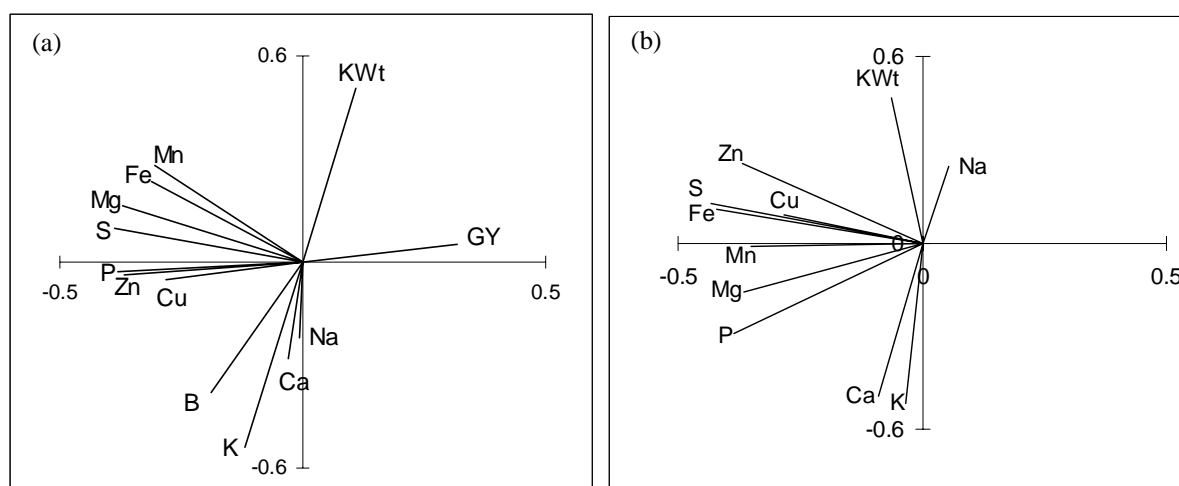


Fig. 1. Biplot of the grain-nutrient concentrations, grain yield (GY) and kernel weight (KWt) from (a) 191 accessions of durum wheat and (b) 31 synthetic hexaploid wheat lines. Ranges in grain-Zn concentrations were (a) 12.3-81.3 $\mu\text{g g}^{-1}$ and (b) 27.7-65.6 $\mu\text{g g}^{-1}$.

CONCLUSIONS

Consistent correlations between Zn and Fe, P, Mg, and S over a wide range in grain-Zn concentrations suggests transport to and/or storage of these nutrients in the grain are linked.

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