Grain Mineral Concentrations in Great Plains Hard Winter Wheat

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INTRODUCTION

- In their efforts to feed the growing world population, wheat breeders have focused primarily on grain yield. As grain yields have increased, concentrations of important minerals have tended to decrease due to a "dilution effect."
- Changes in global CO_2 concentration are anticipated to decrease wheat grain protein and mineral concentrations 5 to 10% over the next 40-60 years (Myers et al. 2014).
- The purpose of this study was to assess variation for grain mineral concentration within the Great Plains Hard Winter Wheat germplasm and to explore relationships with grain protein concentration (GPC) that may be used for selection within breeding programs.

MATERIALS AND METHODS

Genetic Materials

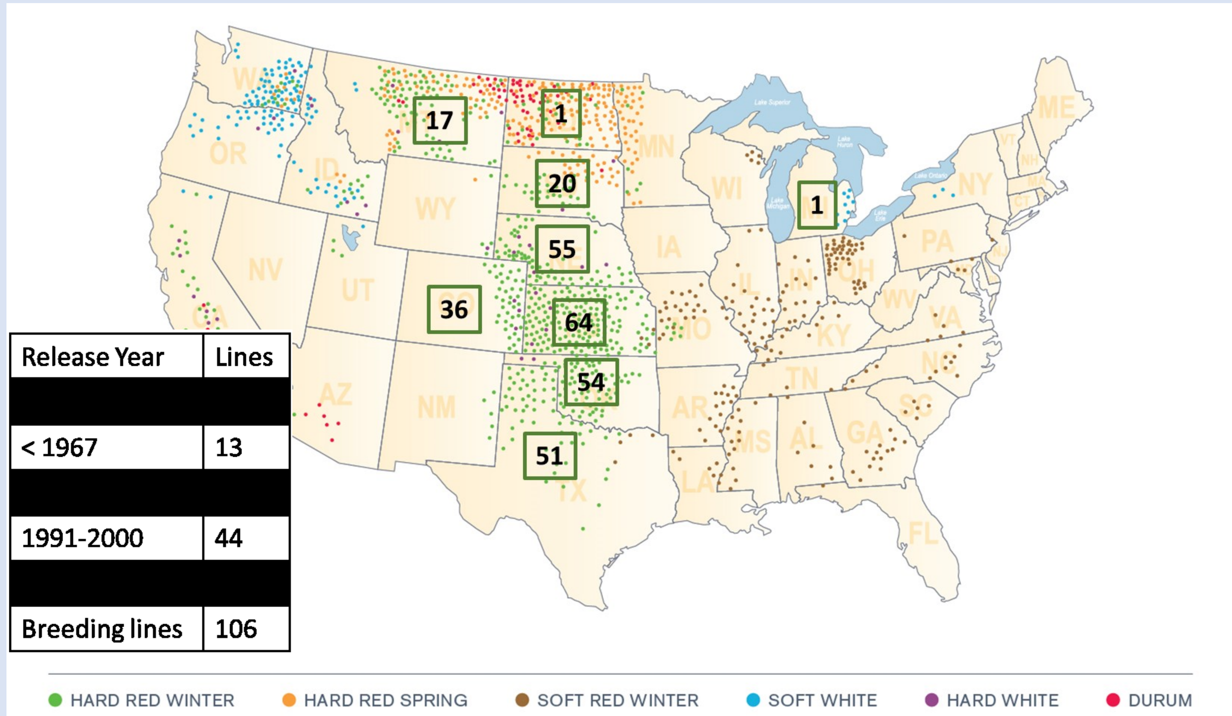

Figure 1. Origins of the 299 lines included in the panel.

Field Trials

We evaluated grain mineral concentration from 2 locations (Ithaca, NE and Tipton, OK) in 2 years (2012 and 2013). Genotypes were arranged in an augmented design with 20 test genotypes and 2 check genotypes (Jagger, Settler CL) in each of 15 blocks within a main plot. Two main plots were sampled from each trial. Grain protein was measured in Nebraska trials by NIR reflectance calibrated to combustion analysis.

Mineral Analysis

- 2 g dried grain wet ashed with $HNO_3 + H_2O_2$
- Analysis by ICP-mass spectrometry: Agilent 7500cx ICP-MS Ar carrier; He collision cell; duplicate injections; 50 ppb Ga internal standard

Statistical Analysis

Due to genotype x environment interactions, data were analyzed within each NE trial and across both OK trials.

REFERENCES

Myers et al. 2014. *Increasing CO_2 threatens human nutrition.* Nature 510(7503):139-142.

CONTACT

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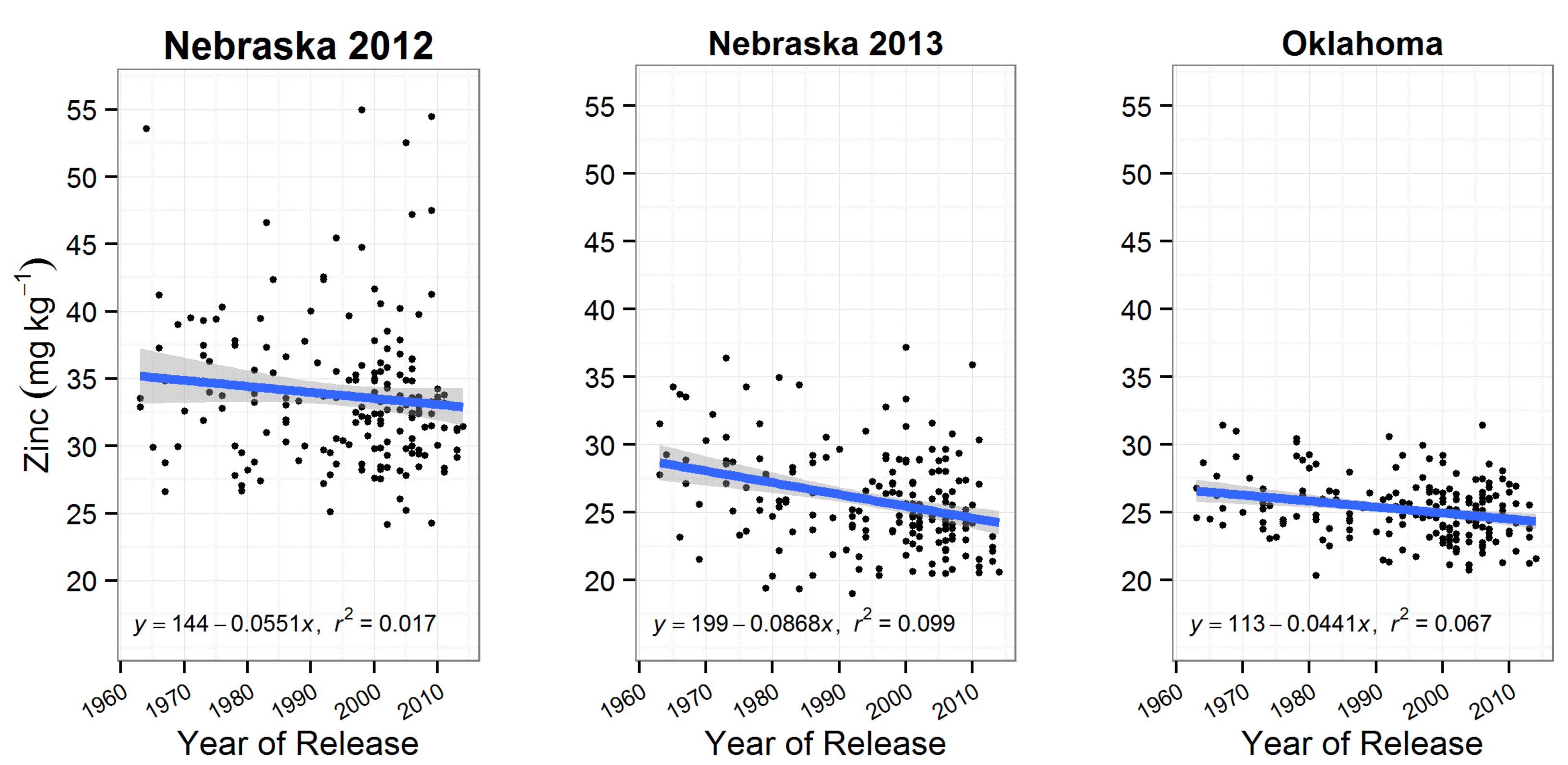
Have Cultivar Grain Concentrations Changed with Year of Release?

Figure 2. Grain Zn concentration and grain yield vs release year for 183 cultivars released after 1960.

Grain Zinc Concentration



Grain Yield

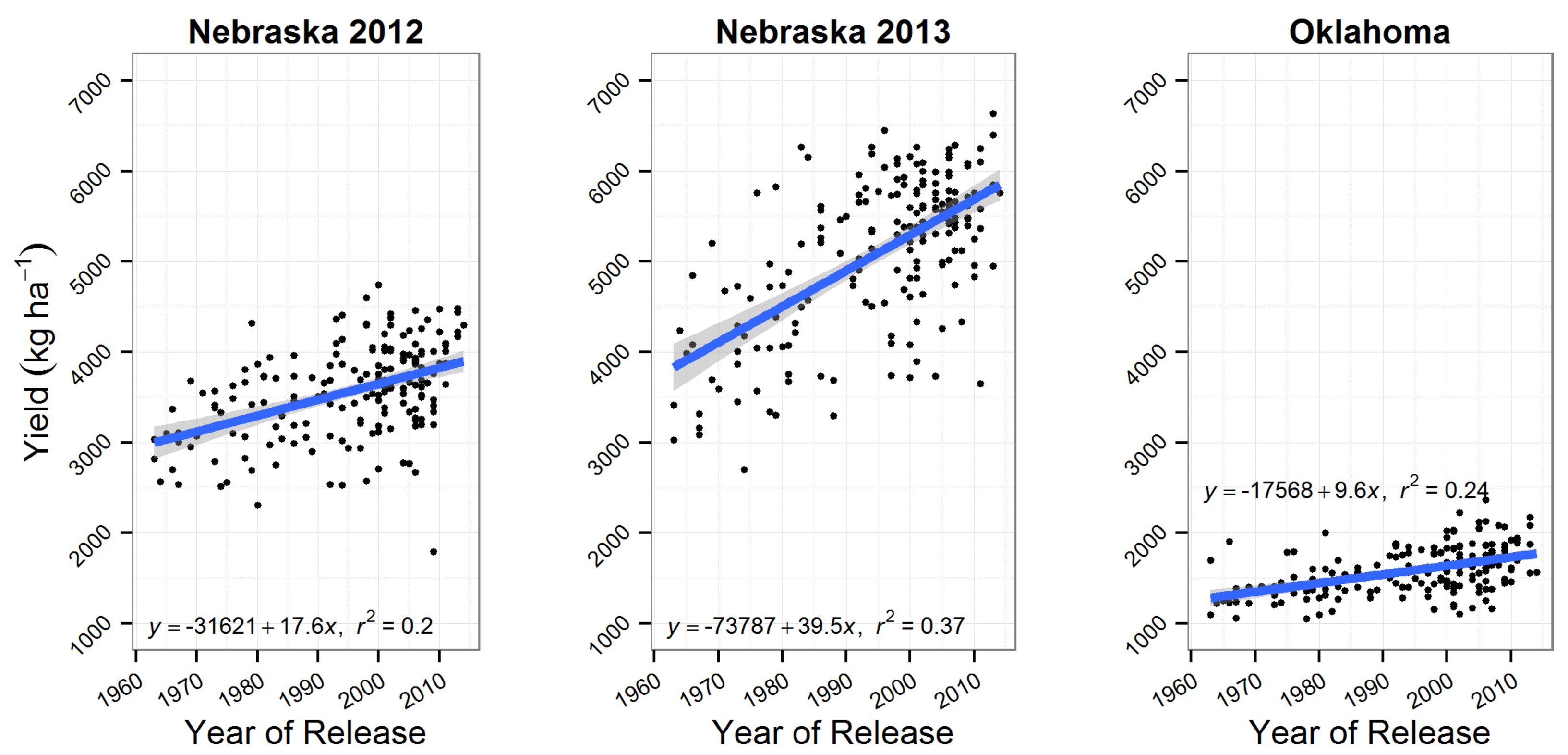


Table 1. Changes in grain Zn, Fe, S, and P concentration and grain yield with year of release for cultivars released after 1960.

	Slope (mg kg^{-1}yr^{-1})	Relative slope (% yr^{-1})*	F-test
Zn			
NE 2012	-0.055 ± 0.031	-0.16	3.1 (*p*=0.08)
NE 2013	-0.087 ± 0.019	-0.26	20.0***
OK	-0.044 ± 0.012	-0.17	13.1***
Fe			
NE 2012	-0.006 ± 0.003	0.00	0.0 ns
NE 2013	-0.099 ± 0.028	-0.13	12.4***
OK	-0.032 ± 0.012	-0.22	7.0**
S			
NE 2012	-0.37 ± 0.90	-0.02	0.2 ns
NE 2013	-3.11 ± 1.11	-0.16	7.8**
OK	-1.42 ± 0.62	-0.10	5.2*
P			
NE 2012	-0.72 ± 2.11	-0.02	0.1 ns
NE 2013	-8.10 ± 2.74	-0.17	8.8**
OK	-5.01 ± 1.61	-0.11	9.6**
Grain yield (kg ha^{-1} yr^{-1})			
NE 2012	17.6 ± 2.6	0.58	46.3***
NE 2013	39.5 ± 3.8	1.25	107.5***
OK	9.6 ± 1.3	0.70	55.9***

* Relative to 'Scout 66'

CONCLUSIONS

- Concentrations of some minerals have decreased
- Mineral concentrations have decreased less than yields have increased
- Variance explained by regressions is poor: opportunity for improvement by breeding remains.

Can Breeding Increase Mineral Concentrations?

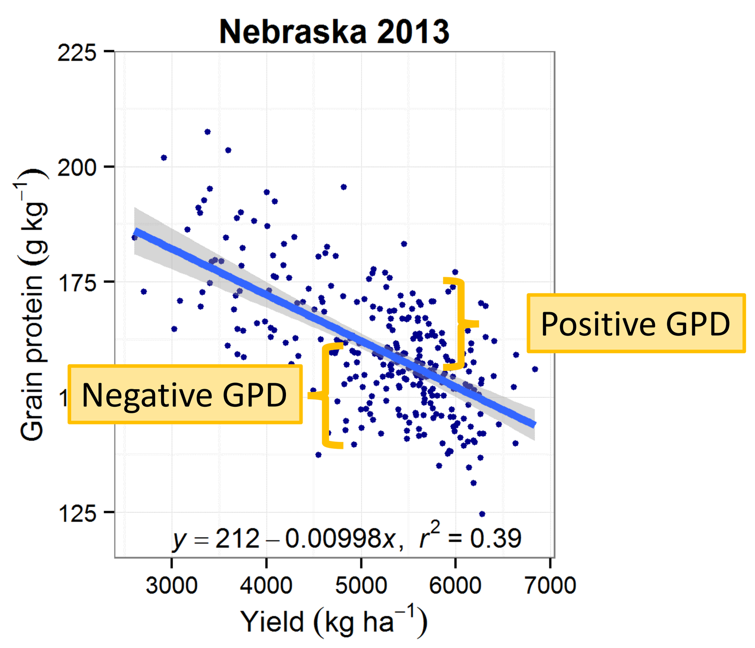
Table 2. Ratios of genetic variance to *g x e* variance across four trials.

	$\sigma_g^2/\sigma_{g\times e}^2$
Grain yield	0.49
Fe	0.33
Zn	0.42
S	0.06
P	0.28

Table 3. Partial correlations of Zn, Fe, and grain protein concentration, controlling for yield.

Environment	$r_{(Zn,GPC.Yield)}$	$r_{(Fe,GPC.Yield)}$	$r_{(Zn,Fe.Yield)}$
Nebraska 2012	0.54***	0.41***	0.70***
Nebraska 2013	0.46***	0.47***	0.66***

Figure 3. Grain protein – yield relationship in 2013 and grain protein deviation (GPD).



CONCLUSIONS

- Ratios of genetic variance to *g x e* variance are unfavorable for breeding (Table 2).
- Correlations of Zn and Fe with grain protein have basis beyond common dilution with increased grain yield (Table 3).
- Grain protein deviation (GPD) is a heritable parameter for yield-neutral selection for improved grain protein concentration (Figure 3 & 4, Table 4).
- Genotypes with consistently positive GPD had 6% greater Fe and Zn concentrations than genotypes with consistently negative GPD (Table 5). Selection for positive GPD may improve mineral concentrations.

Table 4. Individual, joint, and conditional frequencies of positive grain protein deviation (GPD).

	$p(GPD > 0)$, [95% CI]
Nebraska 2012	0.50, [0.44, 0.56]
Nebraska 2013	0.48, [0.42, 0.54]
Nebraska 2012 ∩ Nebraska 2013	0.32, [0.26, 0.37]
Nebraska 2013 | Nebraska 2012	0.63, [0.55, 0.71]

Table 5. Grain protein concentration, grain yield, and grain Zn and Fe concentrations of genotypes grouped by GPD in two years of Nebraska trials.

Trials with GPD > 0	Lines	Grain protein (mg kg^{-1})	Grain Yield (kg ha^{-1})	Grain Zn (mg kg^{-1})	Grain Fe (mg kg^{-1})
0	100	153 a	5000 a	24.9 a	35.4 a
1	104	160 b	5290 b	25.8 ab	36.4 ab
2	95	168 c	5290 b	26.5 b	37.7 b

Figure 4. Grain protein deviation (GPD) in 2013 vs 2012.