Genetic Variation for Grain Cadmium Concentration in Great Plains Hard Winter Wheat

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University of Nebraska Lincoln — Pioneering new frontiers.

Triticeae CAP — Coordinated Agricultural Project

USDA — United States Department of Agriculture — National Institute of Food and Agriculture

INTRODUCTION

- Cadmium consumption is a risk to human health, and cereals are a dominant source of Cd in human diets.
- Cd is a particular concern in areas with high-Cd soils.
- Variation in grain Cd concentration in durum wheat is well documented; variation in grain Cd concentration within bread wheat is less characterized.

MATERIALS AND METHODS

Hard Winter Wheat Association Mapping Panel

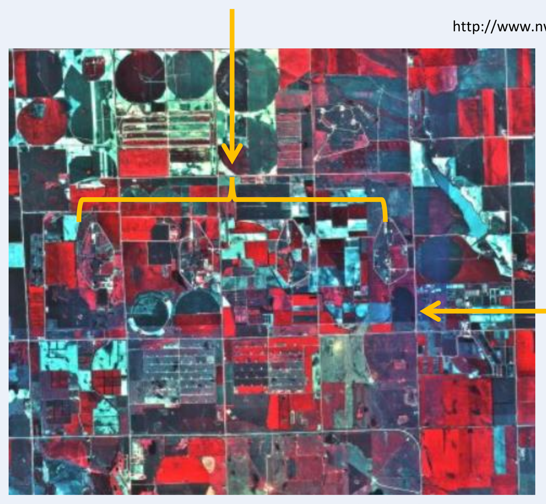
University of Nebraska Agricultural Research and Development Center (ARDC), near Ithaca, NE.

DTAP-extractable Cd concentration = 0.27 mg kg^{-1}

- Genetic Material: 300-entry hard winter wheat association mapping panel. Temporally and geographically diverse.
- Experimental Design:
  - Split plot arrangement of a randomized complete block design: nitrogen rate (44, 88 kg ha^{-1} residual + applied) as main plot; genotype as subplot; 2 reps.
  - Genotypes arranged in augmented design: 15 blocks of 2 check genotypes + 20 entries within each main plot.

UNL-ARDC TRIAL SITE

US Army Corps of Engineers, Kansas City District http://www.nwk.usace.army.mil/Missions/Environmental/EnvironmentalProjects/NOP/ProjectHistory.aspxd



Virtual Nebraska Image Archive http://casde.unl.edu/imagery/cir/index.php?county=saunders&city=mead

Figure 1. Historical images of the Nebraska Ordnance Plant, color infrared aerial image of the area surrounding the ARDC, and color photograph of the 2012 trial area.

Multi-Location Trials

- UNL Wheat Breeding trials at Clay Center, North Platte, Lincoln, and Sidney, NE. USDA-ARS trial (AYT) at ARDC.
- Genetic Material: Two pairs of genotypes
  - Overland (low-Cd)/Wesley (high-Cd)
  - NE05548 (low-Cd)/Freeman (high-Cd)

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

REFERENCES

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- R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org
- H. Wickham. ggplot2: elegant graphics for data analysis. Springer New York. 2009.

CONTACT

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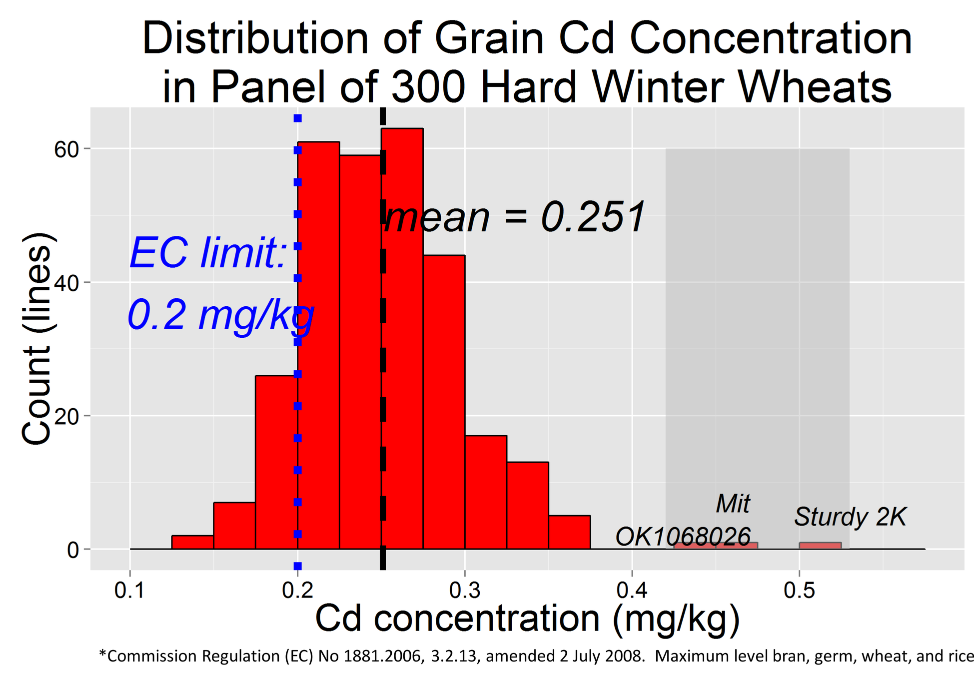
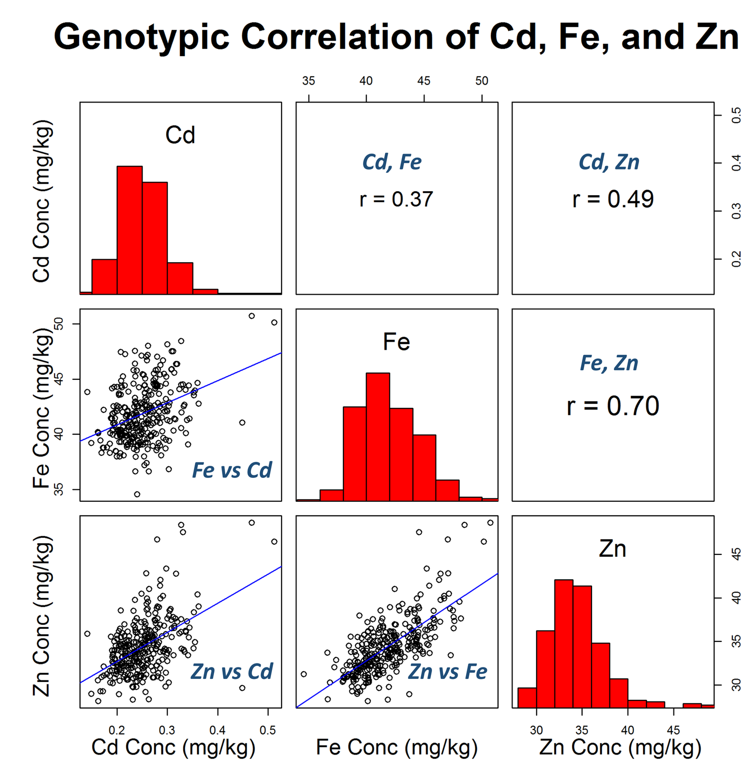
Figure 2. Grain cadmium in the hard winter wheat AM panel grown in 2012 at the UNL ARDC.





Frequency distribution on diagonal; pairwise correlation coefficients above diagonal; pairwise scatterplots with linear fit below the diagonal.

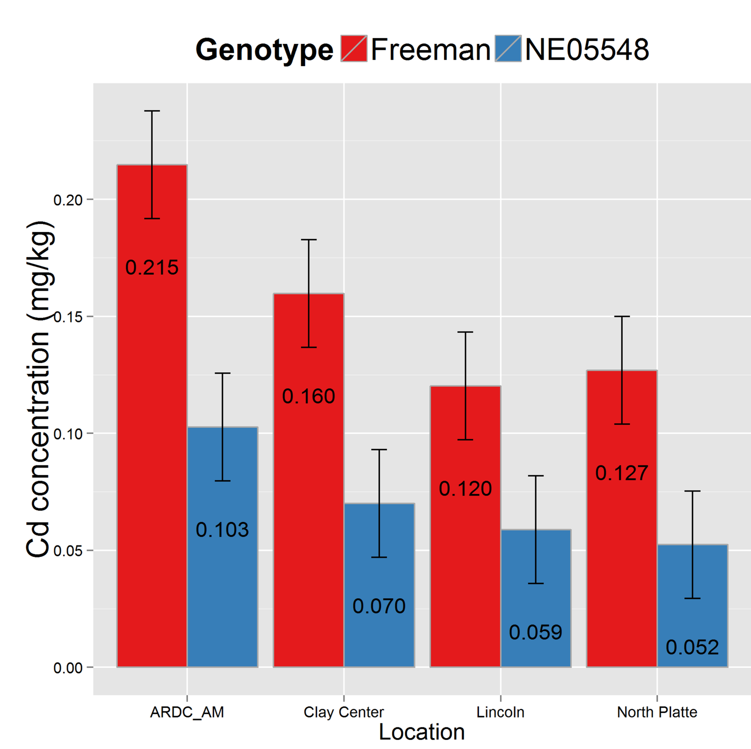
CONCLUSIONS

- High mean grain Cd (0.251 mg kg^{-1}) *and* notable high-Cd genotypes
- High-Cd soil: 0.27 mg kg^{-1} DTAP-extractable Cd
- Same trial near Tifton, OK: $\overline{Cd} = 0.015; Cd_{max} = 0.027$
- Weak relationship of Cd concentration with Fe, Zn concentrations
- Significant genetic variance

Table 1. Genetic and error variances of grain Cd, Fe, and Zn in the hard wheat AM panel.

	Cd	Fe	Zn
σ^2_{geno}	3.03 x 10^{-3}	12.9	16.3
σ^2_{error}	1.82 x 10^{-3}	23.0	16.9

Figure 3. Multi-location evaluation of grain Cadmium concentration in four hard winter wheat genotypes.



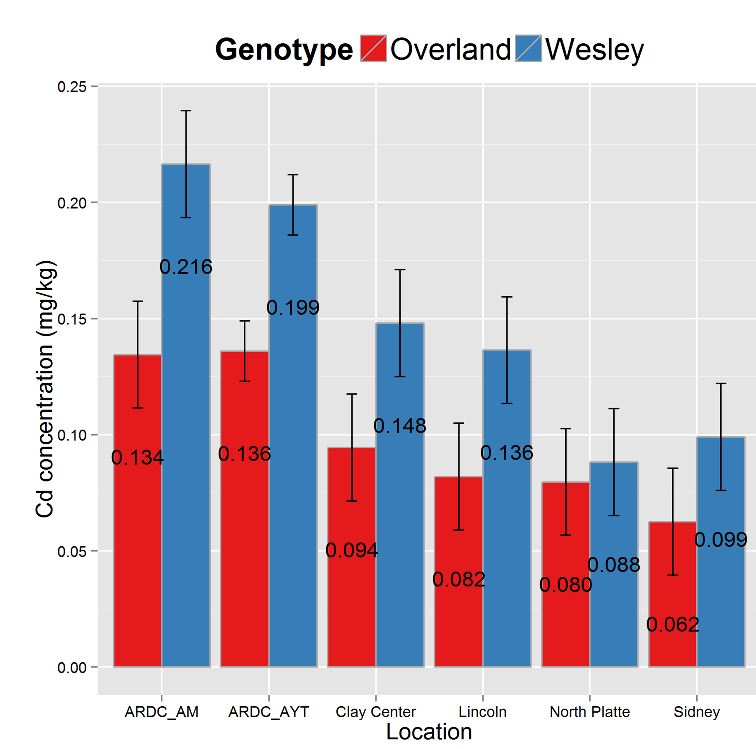
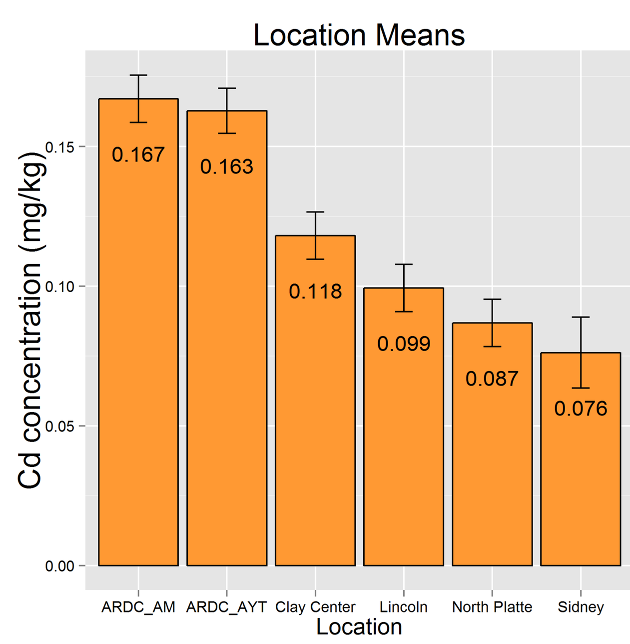
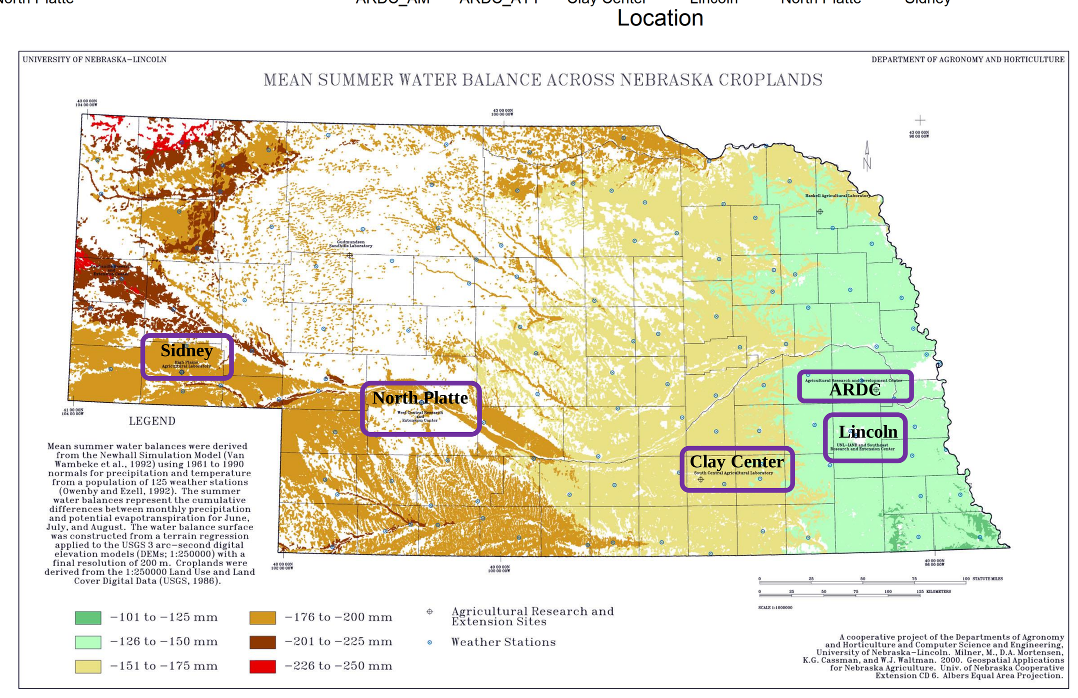


Table 2. Mean† grain cadmium concentration in two pairs of genotypes grown in multiple NE locations in 2012.

	Cd (mg kg^{-1})	p(Diff)
Freeman	0.156	<0.001
NE05548	0.072	
Overland	0.097	<0.001
Wesley	0.150	

†Least squares means over locations: Freeman and NE05548, *n*=4 locations; Overland and Wesley, *n*=6 locations

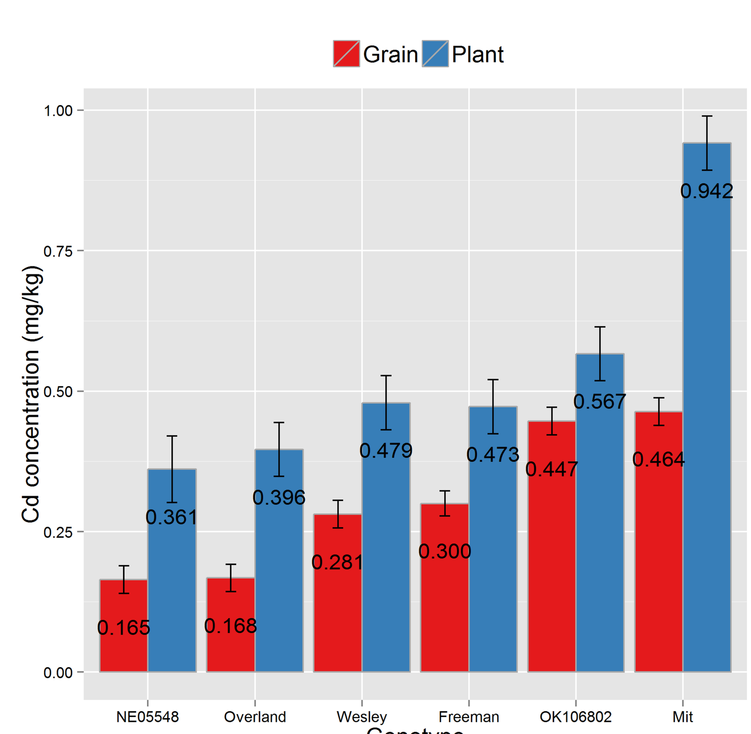


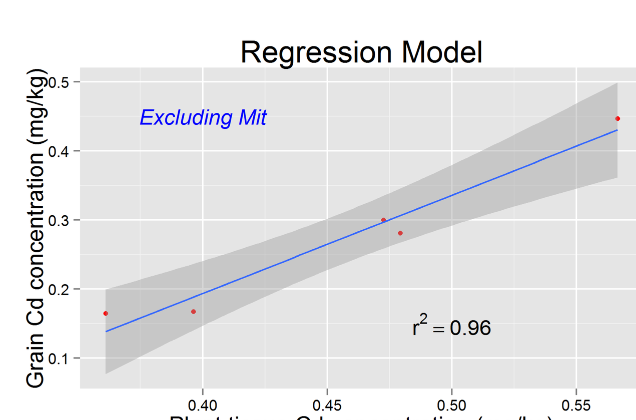


CONCLUSIONS

- ARDC is a uniquely high-Cd environment.
- Genotypes rank consistently across locations.
- Limited $G \times E$ indicates potential for improvement with breeding.

Figure 4. Cadmium concentration in grain and in vegetative plant tissue at anthesis.





CONCLUSIONS

- Grain Cd and plant tissue Cd concentrations are positively correlated.
- Grain Cd concentration better differentiates genotypes than plant tissue Cd concentration.
- Results were consistent with a role for plant uptake/translocation in grain Cd accumulation.

NEXT STEPS

- Analysis of 2013 grain samples in progress.
- Association analysis with genetic marker data will provide insight into the underlying genetics.