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

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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

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 HNO₃ + H₂O₂
• 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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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: Cd = 0.015; Cd = 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.

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Fe</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>a²_0</td>
<td>3.03 x 10⁻²</td>
<td>12.9</td>
<td>16.3</td>
</tr>
<tr>
<td>a² ERROR</td>
<td>1.82 x 10⁻³</td>
<td>23.0</td>
<td>16.9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Cd (mg kg⁻¹)</th>
<th>p(Diff)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeman</td>
<td>0.156</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NE05548</td>
<td>0.072</td>
<td></td>
</tr>
<tr>
<td>Overland</td>
<td>0.097</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Wesley</td>
<td>0.150</td>
<td></td>
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CONCLUSIONS
• ARDC is a uniquely high-Cd environment.
• Genotypes rank consistently across locations.
• Limited G×E indicates potential for improvement with breeding.

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

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.

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

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

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

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The authors wish to thank Dr. Javier Seravalli of the Redox Biology Center at the UNL for the instrumental analyses.
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