

PROJECT NO: BJKT09

TITLE: Factors affecting cadmium uptake by wheat from Idaho soils

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JUSTIFICATION: Idaho has diverse agricultural environments where five classes of wheat can grow. An emerging production concern in the Pacific Northwest wheat growing region is that some wheat grains contain cadmium (Cd) levels that exceed industry tolerances. Cadmium is poisonous for human consumption, and in addition to tighter industry standards, it is predicted that international Codex regulations controlling allowable Cd concentrations in food products will be reduced. Thus, to best position Idaho wheat growers for industry and regulatory food safety criteria, we propose to conduct research to develop the best agronomic practices to limit Cd uptake by wheat grown in Idaho soils.

HYPOTHESIS & OBJECTIVES: We hypothesize that Cd uptake by plant variety varies with Cd bioavailability in soils, and also varies based on agronomic practices (e.g, irrigation or rain fed, nutrient applications, etc.). In addition, we hypothesize that uptake of Cd is directly affected by root physiology, which varies between different genotypes. In FY2015 we characterized soil Cd concentrations and bioavailability at three research center sites (Aberdeen, Kimberly, and Tetonia; see attached Annual Report). In the second year of this project, we will continue to pursue the research objectives proposed in the first year, and have added an additional objective. The objectives of this project are:

1. Characterize Cd content of soils and bioavailability at Moscow and Soda Springs.
2. Investigate the mechanisms of Cd uptake and transport in wheat genotypes, and identify the plant traits associated with low Cd accumulation in grains.
3. Use genomic analysis methods to analyze sequence difference in wheat varieties that show varying amounts of Cd uptake to allow for use of gene marker identification methods in breeding program.

PROCEDURES:

Objective 1: In FY 2016 we propose to expand the study sites to Moscow and Soda Springs. A second year of Aberdeen sampling will also be sampled. Paired sampling of soil and grain samples from the sites will be collected prior to harvest. Soil samples will be taken from each field site from three depths (to 60 cm). We anticipate 45 soil samples from the 3 sites (3 sites × 5 points per site × 3 depths). Soil and wheat samples will be analyzed for total Cd, Zn, Cu, Fe, and Mn. Extractable Cd from the soils will be measured as a proxy for Cd bioavailability using a buffered 0.005 M DTPA extraction test (Fang, Wen, et al., 2007, Meers, Du Laing, et al., 2007). Initial soil characterization will measure total organic matter and pH. From the preliminary analyses, select samples (<20) will be analyzed for particle-size distribution, cation exchange capacity, electrical conductivity, carbonate content, and iron oxide content. Principal component analysis will be done to identify the most important factors for Cd uptake by wheat grain, which will be used in regression analysis to develop predictive relationships.

Objective 2: A pot study in the greenhouse will be conducted with 3 Cd levels and 2 wheat genotypes (LCS-Star and UI Platinum). All the pots will be arranged following a randomized complete block design with 6 replicates. All pots will be filled with the typical surface soil at Aberdeen, Declo loam. Cadmium will be applied as CdCl₂ through irrigation at 0, 1, and 2 times

of current Cd levels at Aberdeen. During the season, 1-2 panicles will be harvested from each plant at 7, 14, and 28 days post-anthesis, and dried at 70 °C for 48 h. At final harvest, all plants will be separated by panicles, leaves, stems, and roots, and dried at 70 °C. The roots will be rinsed, analyzed for morphological characteristics using WinRHIZO systems. Representative subsamples of panicles during the season and plant parts at the final harvest (i.e., leaves, stem, grains, and roots) will be analyzed for Cd content.

Objective 3: GBS (genome by sequencing) will be used to analyze sequence differences for the two spring cultivars LCS Star and UI Platinum used in Objective 2. Single nucleotide polymorphisms (SNP) associated with data for the two spring wheat cultivars generated in Objective 1 (field data) and Objective 2 (GH data) will be determined by association analysis. SNPs will be validated using data from Objective 1 from both years of grant. It may be necessary to develop a doubled haploid population from UI Platinum x LCS Star to further validate the identified SNPs.

DURATION: Objectives 1- 3 will be done over two years. Soil sampling and analysis will be completed the first year. Greenhouse experiments and gene marker identifications will be started first year and completed second year.

COOPERATION: Ardent Flour Mill has agreed to analyze up to 600 grain samples for total Cd, Zn, Cu, Mn, and Fe content. The cost for the Objective 3 will be paid by Dr. Chen's TCAP budget, therefore is not requested from IWC.

ANTICIPATED BENEFITS/EXPECTED OUTCOMES/INFORMATION TRANSFER:

By the end of this project, we will provide low uptake Cd cultivars, desirable fertilizer and irrigation management practices in different Idaho soil environments, genetic tools (markers and traits) for selecting low Cd uptake cultivars. This new knowledge will increase sustainability of wheat production in Idaho, PNW, the US, and the world. New variety information and best management information to grow low-Cd wheat in Idaho will be presented in Cereal School, tri-state convention, grower meetings, national meetings. The results will be prepared in annual reports for the IWC, and published in peer-reviewed journals. The results will also be used to apply the competitive grants in NIFA or other agencies.

LITERATURE REVIEW:

Ingestion of Cd causes diseases such itai itai disease, renal dysfunction, osteoporosis, cancer, and cardiovascular disease. High consumption levels of grains by humans are a concern for Cd (Clemens, Aarts, et al., 2013), and there is increasing pressure to limit Cd uptake into the food supply. Typical concentrations of Cd in wheat grains ranges from 0.008 to 0.26 mg/kg (Kabata-Pendias and Pendias, 2001). According to the Codex Commission (2009), maximum allowable Cd concentrations for wheat grain as a human food is 0.2 mg/kg. Ardent Mills (Weaver, personal communication) is meeting an industry standard of 0.025 mg/kg for certain food sources.

Cadmium accumulation by plants is influenced by many factors, including bioavailable Cd in the soil, soil chemistry, climate, agronomic practices (e.g., irrigation water quality parameters and application methods, and fertilizer application timing), and plant genotype (Baize, Bellanger, et al., 2009, Clemens, Aarts, et al., 2013). Common sources of Cd to agricultural crops are fertilizers (especially phosphorus fertilizer) (Grant et al., 2013) and amendments added to soils (such as sewage sludge). Median Cd concentrations in agricultural soils in the US are 0.4 mg/kg, with an upper limit of 2 mg/kg (Holmgren et al., 1993). Bioavailability of the Cd for plant uptake is not the same in all soils. For example, a soil with higher total Cd concentration can have less

bioavailable Cd than a soil that has lower total Cd concentration. Cd bioavailability is a function of the soil properties and plant biochemistry.

Differences in plant Cd uptake could derive from root Cd uptake and retention, root-to-shoot translocation, and redistribution of Cd within shoot (Clemens et al., 2013). The accumulation of Cd varies at different stages and at different plant parts (Harris and Taylor, 2013). The high root uptake could be related to greater root surface area and more root tips for Cd absorption (Greger and Landberg, 2008). Root architecture varies by variety, and understanding the mechanisms responsible for genotypic variation in Cd accumulation in grain will accelerate breeding efforts (Clemens et al., 2013; Grant et al., 2008). Compared to Durum, limited research has been conducted on Cd source and bioavailability. Based on preliminary screening, Cd concentration of SE Idaho bread wheat ranged from 0.013 to 0.169 mg/kg over five different environments. This suggests that we can manipulate Cd concentration through breeding and agricultural management practices to achieve low Cd wheat concentrations. Coupling variety selection to best agronomic practices is a promising area of research for meeting targeted maximum allowable Cd concentrations in wheat, and to make the industry sustainable.

References

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IDAHO WHEAT COMMISSION - BUDGET FORM

Allocated by	Idaho Wheat Commission	during FY 2014	\$	-
Allocated by	Idaho Wheat Commission	during FY 2015	\$	37,500

REQUESTED FY 2016 SUPPORT:

	Salary	Temporary Help	Fringe	Travel	OE	Grad Fees	TOTALS
Idaho Wheat Commission	\$ 5,000	\$ 5,000	\$ 2,250	\$ 2,280	\$ 18,168	\$ -	\$ 32,698

OTHER RESOURCES (not considered cost sharing or match):

TOTAL OTHER RESOURCES \$ -

TOTAL PROJECT ESTIMATE FOR FY 2016:	\$ 32,698	\$ -	\$ 32,698
	<i>(Requested)</i>	<i>(Other)</i>	<i>(Total)</i>

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

	<i>Strawn</i>	<i>Llang</i>	
Salary	\$ 5,000	\$ -	
Temporary Help	\$ 3,500	\$ 1,500	
Fringe Benefits	\$ 2,115	\$ 135	
Travel	\$ 2,280	\$ -	
Operating Expenses	\$ 5,648	\$ 12,520	
Graduate Student Fees	\$ -	\$ -	
TOTALS	\$ 18,543	\$ 14,155	
Total Sub-budgets \$			32,698

10.24.2014 - Version