PROJECT NO: BJKU09, BJKU44, BJKU69

TITLE: Factors Affecting Cadmium Uptake by Wheat from Idaho Soils

PERSONNEL: Dan Strawn, Xi Liang, Jianli Chen, Juliet Marshall

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JUSTIFICATION: 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. In the past four years, our research has provided soil-grain Cd testing for Idaho, as well as Cd screening information for varieties grown in the region. In FY2018, we tested how P fertilizer amendments affect Cd uptake by grain. We propose to conduct research to complete the field trials of P fertilizer effect on Cd uptake, and a final year of genetic research on plant factors that 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 a genetic trait, which varies between different genotypes. Molecular markers associated with grain Cd content will accelerate variety development of low grain Cd content cultivar. In FY2018, we conducted greenhouse trials to test the hypothesis that phosphorus fertilizer management affects Cd uptake in wheat. In spring 2018 we will plant a field trial to further test this hypothesis. In FY2019, we will harvest the wheat from the field trial and conduct grain analysis for Cd concertation. In FY 2019, we will also finalize work to identify molecular markers associated with Cd uptake, as well as complete the meta-data analysis of paired soil grain analysis of Idaho samples. The project objectives are:

1. Measure how nutrient and lime addition affects Cd uptake in a field trial (continuation of FY18 objective).
2. Identify QTL and molecular markers for low grain Cd content that can be used in low grain Cd variety development (FY17 and FY18).
3. Complete meta data analysis of Cd in Idaho wheat and paired soil analysis.

PROCEDURES:

Objective 1: In FY 2018 we will complete the greenhouse wheat (LCS-Star) growth study to determine if phosphorus fertilizer affects Cd uptake. Based on this study, we will decide on the phosphorus fertilizer amendment rates to be sued in a field trial in Soda Springs. A field experiment will be conducted at Soda Springs to investigate if phosphorus fertilizer can reduce Cd uptake in the grains of spring wheat. Soda Springs is selected as the location of the experiments because the soil is acidic with a high Cd concentration, and grain Cd concentrations in spring wheat were higher than other locations. UI Platinum (low-Cd cultivar) and LC Star (high-Cd cultivar) will be planted under four levels of phosphorus (i.e., zero, recommended, 2X, and 4X). The experiment will follow a randomized complete block design with four replicates, and the plot dimension will be 5×10 ft. Plant samples will be taken from each plot during the growing season to investigate Cd accumulation in the grain. At maturity, all plots will be harvested using a small-plot combine to estimate grain yield of different cultivars under different fertilization treatments. The plants will be harvested in FY2019 and grains will be analyzed for Cd, Mn, Zn, Fe and P content.

Objective 2: We will plant the DH population in Soda and Ashton in spring 2018 and obtain the second year data and do final QTL analysis in spring 2019. We would like to request another year support to finish QTL mapping of Cd.

Objective 3: Data from 2013-2018 on total grain element content (Cd, Zn, P, Fe, Mn) have been compiled, as well as total concentrations in soils from which the grain was sampled. We have conducted preliminary analysis to gain insight into relationships between soil Cd and grain uptake. In FY 2019, we are completing a meta-data analysis using the program Tableau and statistical testing of the data using the program R. A final report will be prepared containing all of the data, analysis, and interpretations.

DURATION: This will be the fifth year of the project. We anticipate the project will be completed this year.

COOPERATION: Ardent Food Mills and Nestle are integral partners in this project.

ANTICIPATED BENEFITS/EXPECTED OUTCOMES/INFORMATION TRANSFER: By the end of this project, we will provide low uptake Cd cultivars, desirable fertilizer management practices, and genetic tools (markers and traits) for selecting low Cd uptake cultivars. 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.

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). 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. Molecular markers associated with low grain Cd content will accelerate variety development and save cost for grain Cd testing. Coupling variety selection to best agronomic practices is a promising area of research for meeting targeted maximum allowable Cd concentrations in wheat.

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IDAHO WHEAT COMMISSION - BUDGET FORM

Principal Investigator: Dan Strawn

Allocated by	**Idaho Wheat Commission**	**during FY 2017**	**$**	**61,445**
Allocated by	**Idaho Wheat Commission**	**during FY 2018**	**$**	**55,132**

REQUESTED FY2019 SUPPORT:

	Salary (*staff, post-docs, etc.*)	Temporary Help	Fringe	Travel	OE	Graduate Tuition/Fees	TOTALS
Idaho Wheat Commission	$ -	$ 8,407	$ 2,046	$ 4,000	$ 21,385	$ -	$ 35,838

TOTAL BUDGET REQUEST FOR FY 2019: $ 35,838

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

	Dan Strawn	*Xi Liang*	*Jianli Chen*	*(Insert CO-PI Name)*
Salary	$ -	$ -	$ -	
Temporary Help	$ 2,880	$ 3,500	$ 2,027	
Fringe Benefits	$ 69	$ 1,148	$ 829	
Travel	$ 1,200	$ 800	$ 2,000	
Operating Expenses	$ 3,485	$ 1,500	$ 16,400	
Graduate Student Tuition/Fees	$ -	$ -	$ -	
TOTALS	$ 7,634	$ 6,948	$ 21,256	

Total Sub-budgets $ 35,838

Explanatory Comments: (see FY2019 RFP for definition)

Fall 2017 Version

ANNUAL REPORT

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ACCOMPLISHMENTS:

We are completing the P fertilizer on Cd uptake in wheat greenhouse experiments. this required two growth trials to get the correct combination of soil and greenhouse conditions to grow the wheat to maturity without stress and pre-heading. Results will be used to design the field trials of P fertilizer to reduce grain Cd being plated in Spring 2018.

We have completed the first phase of meta-data analysis to evaluate paired soil-grain samples from 2013-2017 at several locations throughout Idaho for relationships between soil and Cd uptake. From the analysis we are identify soil samples that might be promising to make additional measurements of soil properties to evaluate plant-soil Cd uptake relationships.

QTL mapping progress in Jianli's lab:

We planted one DH population (UI Platinum x LCS Star) in two high Cd (Soda and Ashton) and one low Cd (Aberdeen) environments, planted an association panel in one high Cd environment in Soda in 2017. Flour samples were send to do Cd test and tentative QTL will be detected in spring 2018.

PROJECTIONS:

The results will provide genetic information on varieties that can be planted to achieve low grain Cd and which soil properties are ideal to achieve low grain Cd concentrations. In addition, the results will answer the questions if liming to affect pH, adding phosphorus fertilizer, or adding Zn will affect Cd uptake in wheat. The greenhouse studies on amendment effects will be followed up with field trials in 2018.

PUBLICATIONS:

Liang X., D.G. Strawn, J. Chen, J. Marshal. 2017. Variation in cadmium accumulation in spring wheat cultivars: uptake and redistribution to grain. Plant and Soil 421: 219-231.