PROJECT NO: BJKT09, BJKT44, BJKT69

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 three years, our research has provided soil-grain Cd testing for Idaho, as well as Cd screening information for varieties grown in the region. The research allowed for initial targeted grain production to meet industry demand. We propose to conduct continued research on the best agronomic practices and to gain genetic information 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 but affected by root physiology, which varies between different genotypes. Molecular markers associated with grain Cd content will accelerate variety development of low grain Cd content cultivar. In FY2017, we characterized soil Cd concentrations and bioavailability at sites in northern and southern Idaho. The goal was to collect a paired soil-grain analysis so as to discover which 2016 crop could be used as a trial for low Cd delivery to the millers. In FY 2018, we will continue work to identify molecular markers associated with Cd uptake and continue the investigation on how nutrient management effects Cd uptake in a greenhouse study. The project objectives are:

1. Measure how nutrient and lime addition affects Cd uptake in a greenhouse study (continuation of FY17 objective).
2. Field trial of soil fertilizer effects on Cd uptake.
3. Identify QTL and molecular markers for low grain Cd content that can be used in low grain Cd variety development (FY17 and FY18).

PROCEDURES:

Objective 1: Based on field data from 2015 and 2016, relationships between soil properties and Cd uptake in grain is being investigated. From this information, hypothesis on relationships of soil metal concentrations (such as zinc and manganese), soil pH, soil organic matter, and nutrient availability are being assessed, and will be tested in a greenhouse study. Two soils have been collected; one with sufficient crop Zn and another with deficient crop Zn. The initial study will use one wheat genotype (LCS-Star or UI Platinum). A follow up study to further test soil properties and amendments, or effects of another wheat variety will be done; the studies will be done sequentially to allow a more informed hypothesis to be tested in the second trial. All the pots will be arranged following a randomized complete block design with 6 replicates. All pots will be filled with the surface soil (a soil from southern Idaho can be tested in the second greenhouse study). In the first study, we are trying Zn fertilizer as an amendment to discern how it affects Cd uptake in wheat. At final harvest, grains will be analyzed for Cd content.

Objective 2: Two field experiments will conducted at Soda Springs to investigate if fertilization of Zn and lime 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. In each experiment, UI Platinum (low-Cd cultivar) and LC Star (high-Cd cultivar) will be planted under three levels of Zn or lime (i.e., zero, medium, and high). Fertilizer application amounts will be based on the results from the greenhouse study. Each 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, and the grains will also be analyzed for Cd concentrations. Zn and lime fertilizations are expected to reduce Cd uptake in both cultivars.

Objective 3: Two bi-parental populations (192 doubled haploids) will be planted in headrow plots on the second year in Ashton, Soda, and Aberdeen in the spring of 2017. The harvested grain sample will be tested for Cd content. The grain Cd data from two years along with the SNP data will be analyzed with genomics software (Mapmaker and Window Cartographer) and QTL/molecular markers will be identified and used in the breeding program.

DURATION: This will be the fourth year of the project. We anticipate a fifth year to complete the field trial study of fertilizer amendments (Objective 2).

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 in different Idaho soil environments, 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

Allocated by	**Idaho Wheat Commission**	**during FY 2016**	**$**	**32,698**
Allocated by	**Idaho Wheat Commission**	**during FY 2017**	**$**	**61,445**

REQUESTED FY2018 SUPPORT:

	Salary	Temporary Help	Fringe	Travel	OE	Graduate Tuition/Fees	TOTALS
Idaho Wheat Commission	$ 8,128	$ 5,527	$ 2,424	$ 4,000	$ 29,880	$ 5,173	$ 55,132

TOTAL BUDGET REQUEST FOR FY 2018: $ 55,132

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

	Strawn	*Liang*	*Chen*
Salary	$ 8,128	$ -	$ -
Temporary Help	$ -	$ 3,500	$ 2,027
Fringe Benefits	$ 163	$ 1,432	$ 829
Travel	$ 1,500	$ 500	$ 2,000
Operating Expenses	$ 6,480	$ 7,000	$ 16,400
Graduate Student Tuition/Fees	$ 5,173	$ -	$ -
TOTALS	$ 21,444	$ 12,432	$ 21,256

Total Sub-budgets $ 55,132

Explanatory Comments: (see FY2018 Guidelines for definition)
In FY 2017 IWC supported a gradaute student research associate to work on the project. FY 2018 is the second year required for the MS student support to continue work on the project (note: the student is also working on a project to understand soil acidification in northern Idaho soils (in conjunction with Kurt Schroeder)

11.21.2016 - Version

ANNUAL REPORT

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ACCOMPLISHMENTS:

We have begun preparation of the greenhouse experiments to test the effects of Zn and P fertilizer on Cd uptake in wheat. This required measurement of available (DTPA extractable) Cd and Zn from soils collected in 2016 from the paired soil-grain analysis study. The available metals analysis have been completed. This data will be combined with the 2014 and 2015 data to allow a survey of Idaho soils from wheat growing regions. The survey of available metals will be used to select two soils for the greenhouse study: 1) a low Zn soil, and 2) a high Zn soil. We plan to collect the soils for the greenhouse study in the next six weeks, and conduct the greenhouse study in winter 2017.

We worked with the IWC and Ardent Food Mills (AFM) to select several paired soil-grain samples to analyze for total Cd analysis. The goal was to provide some grain that could be used as a low Cd milling source. We have completed he collection of samples, and submitted them for analysis. Results have been received from the grain analysis.

QTL mapping progress in Jianli's lab:

1. Increased seed of mapping population.
2. Collected grain sample from one Cd location and being tested for grain Cd content.
3. DNA of DHLs in the population will be extracted and genotype in the spring of 2017.
4. The population will be planted in three locations in spring 2017 and tested for grain Cd content.

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. 2016 (in revision). Cadmium Accumulation in Spring Wheat Grains as Influenced by Variety and Root Length.

Results from the greenhouse and field studies in 2015 were presented as "Differences in Cadmium Accumulation and Root Morphology in Spring Wheat Varieties with Distinctive Grain Cadmium Concentration" at Agronomy Society of America, Crop Science Society of America, and Soil Science Society of America Annual Meetings at Phoenix, AZ during November 6-9 2016.