Evaluation of Lentil Germplasm for Arsenic Uptake

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Abstract

Arsenic contamination of groundwater, surface water and land is a public health issue throughout the world. Arsenic can be taken up from soil by plants and accumulate in vegetative and reproductive plant tissues where they pose a human health threat through consumption, inhalation or touch. Different plant species and genotypes within species have varying abilities to detoxify, sequester or remove arsenic from their cells. A common mechanism contributing to low arsenic uptake in crops is the shutdown of phosphate transporters designed to function in low soil P conditions ("high affinity phosphate transporters"). The studies described here sought to address variation for arsenic uptake in lentil genotypes and the relationship of that variation to phosphorus. Lentils (*Lens culinaris*) are an important source of dietary fiber worldwide especially in the Middle East, Asia, and North Africa. Major lentil-producing countries that have agricultural lands impacted by toxic levels of arsenic include China, India and Bangladesh. Cultivar differences for arsenic uptake have been tentatively identified in lentils.

Introduction

Throughout the world, there are regions where agricultural productivity has been compromised by arsenic contamination (Figure 1). There are three common sources of contamination:

- Historical use of arsenical pesticides, particularly in areas devoted to rice paddies or tree fruit production.
- Natural sources of groundwater contamination, e.g. the Bengal Delta.
- Mining-related arsenic contamination, e.g. the Silver Valley in North Idaho.

As a phosphate analogue, arsenic can be transported into plant roots using plant phosphorus transporters, where it interferes with glycolytic metabolism, mitochondrial respiration and can bind thiol-based peptides. This results in reduced yields and poses a health threat. Currently, a public health crisis is unfolding in Bangladesh, where an estimated 1 in 5 deaths is directly attributable to arsenic poisoning due to drinking contaminated groundwater and eating contaminated crops.

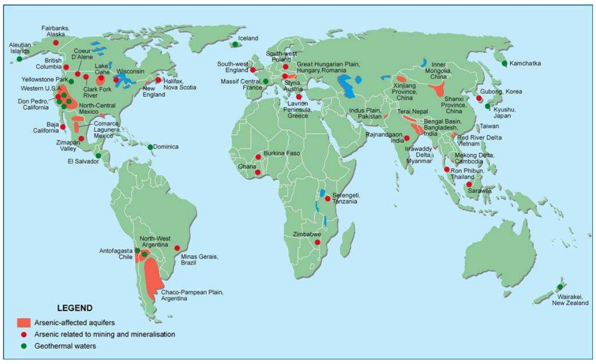

Figure 1: Map of arsenic-affected aquifers across the world. Source: British Geologic Survey, 2012

Materials and Methods

Two greenhouse experiments have been conducted. The objective of the first was to understand how arsenic uptake in two lentil cultivars is affected by increasing doses of arsenic. Two lentil cultivars were grown under 0, 5, 10, 20, and 40 mg/L (ppm) of arsenic supplied in 2 treatments for 13 weeks. The tissue was harvested, dried, weighed and analyzed for total arsenic concentration using ICP-AES. The cultivars were chosen for their differing concentrations of seed phosphorus (Figure 2).

The objective of the second greenhouse experiment was to examine how a single arsenic treatment affected the biomass and arsenic accumulation in roots and shoots across a large panel of genetically diverse lentil genotypes. Fifty-two lentil accessions were chosen from the USDA lentil core, parents of existing mapping populations, and accessions which originated from the Bengal Delta in India and Bangladesh. They were subject to 100 mM AsIII treatment twice per week for 8 weeks. The shoots and roots were separated and saved for total arsenic analysis.

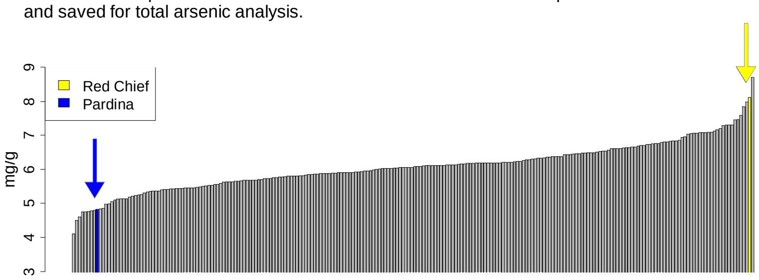

Figure 2. Concentration of phosphorus in seeds in the USDA National Plant Germplasm lentil core collection. Each bar represents an individual accession. Data from Grusak, 2009.

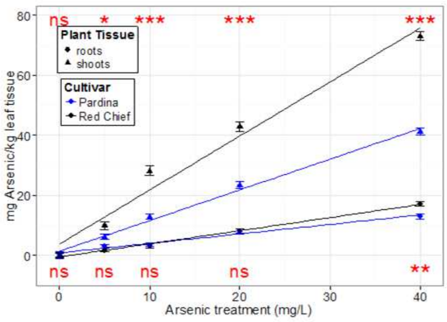

Figure 3. Arsenic uptake curves in roots and shoots for the lentil cultivars Pardina and Red Chief. Stars indicate statistically significant differences (ns = not significant, * < 0.05, ** <0.01, *** <0.001) for pairwise comparisons made at each level of As treatment for the roots (bottom of graph) and shoots (top of graph)

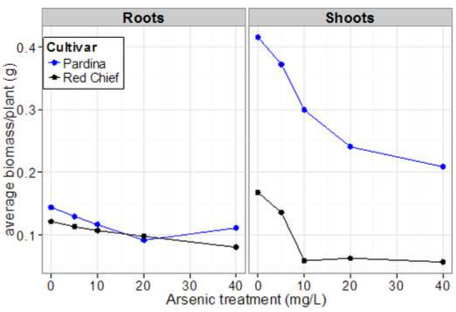

Figure 4. Changes in the root and shoot biomass production for the lentil cultivars Pardina and Red Chief by level of arsenic treatment.

Results

- There were statistically significant differences between the Pardina and Red Chief for arsenic uptake in roots and shoots across multiple concentrations of arsenic treatment (Figure 3).
- The differences in shoot arsenic uptake slopes (change in tissue arsenic concentration per unit As treatment) for the two cultivars was 0.833 for the shoots (Pr<0.0001) and 0.112 for the roots (Pr = 0.0032).
- Due to limitations of equipment, individual biomass measurements could not be taken, but the bulk shoots measurements indicate a pattern of declining biomass with increasing arsenic treatment (Figure 4).
- Preliminary data from the second greenhouse trial indicates genetic differences in plant height and biomass in response to arsenic (Figures 5 and 6)

Conclusions

- These studies present the first evidence of differential arsenic uptake responses in lentil cultivars.
- The identification of markers, genes and mechanisms related to low arsenic uptake will help to further elucidate the plant response to toxic metal stress.
- The introgression of low As uptake traits into adapted cultivars will benefit lentil producers and consumers in regions impacted by high levels of soil and/or ground water arsenic contamination.

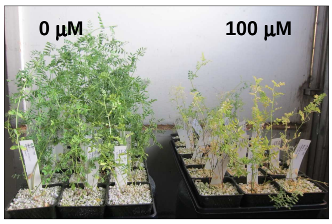

Photo: J. Piaskowski

Figure 5. Lentil cultivars subject to different arsenic treatment levels in experiment II.

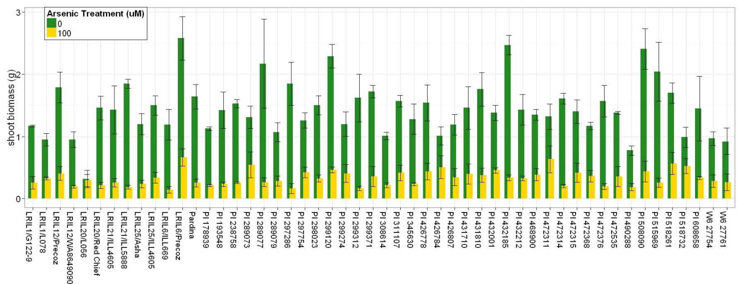

Figure 6. Differences in plant biomass in response to arsenic treatment of 52 lentil accessions.

Acknowledgements

The authors gratefully acknowledge Washington State University BIOAg program for funding this work and the University of Idaho Soil Chemistry Lab for assistance in arsenic analysis.