UMassAmherst | College of Natural Sciences
Center for Agriculture, Food, and the Environment

United States Department of Agriculture
National Institute of Food and Agriculture

Effect of Nano-sulfur on Arsenate toxicity and accumulation in soybean

Minting Zeng, Sudhir Sharma, Om Parkash Dhankher
Stockbridge School of Agriculture, University of Massachusetts, Amherst

Introduction

Arsenic contamination in the food is serious global challenge for human health. The source of arsenic can naturally occur in the groundwater due to the denaturing of the mineral. However, the potential of arsenic exposure had been climbed due to anthropogenic activities such as agricultural pesticides or industrial processes. Agricultural and industrial practices can introduce excessive arsenic contamination to our environment including the groundwater the farmers use for irrigation purposes. The vegetation can absorb the arsenic and stored it in their aboveground tissue which the consumer will feed on; this allows the arsenic to build up in our food chain which poses a severe health effect on the human body. Soybean can be found in hundreds of edible and non-edible products which pose a significant impact on our economy. The arsenic contamination has a negative impact to the soybean crop yield and growth while posing food safety issues to our society. It is urgent to find a method to prevent arsenic from entering our food chain while increase soybean production. The goal of this research is to evaluate the effect of nano-sulfur on As(V) toxicity and accumulation in soybean.

Sulfur is one of the essential nutrients to the plant and to the defense mechanism against heavy metals. The sulfur assimilation pathway is also the key to the plant to the biosynthesis of GSH and phytochelatin both play an important role for the plant to defend under heavy metal stress and help the plant store the heavy metal. In addition to that, the application of nano-sulfur is non-toxic to the human body and safer for our environment compare with other nano-materials. The quantum size of nanoparticles gives them a high cover of surface area with a low application rate which is ideal for agricultural practices. With this being said, assessing the effect of nano-sulfur on soybean production and arsenic bioavailability is critical to the world's future agronomy

Objective

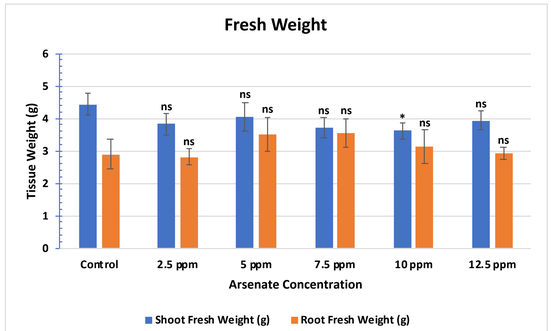
- Investigate the optimum concentration of Arsenate that reduce the soybean yield, growth, and nodule formation.
- Apply the arsenate concentration to the full-scale experiment to see whether the nano-sulfur treatment can prevent arsenate uptake and accumulation in soybean and prevent the loss of plant growth and yield.

Soybean plants treated with Arsenate grown in greenhouse

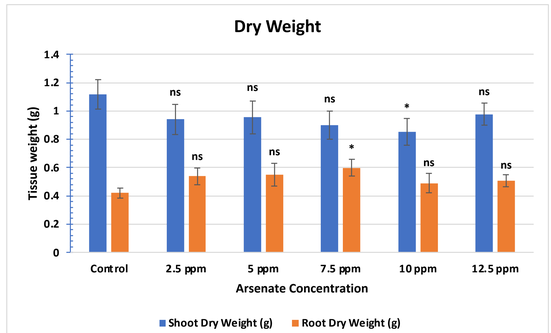
Methodology

Transplant 14 days - old soybean to 6' pot and applied arsenate solution → Mix soil with potting mix with 1:1 ratio; Weight out 800 grams of soil in 6' pot → Water 50 ml of tap water daily → Harvest soybean plant after 3 weeks; Record fresh and dry weight for shoot, root, and nodule → Grind shoot and root tissue; weight out 100 mg of the tissue for acid digestion → Perform elemental analysis with ICP-MS to measure the arsenate concentration

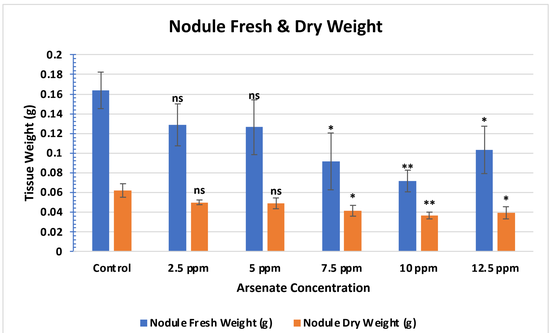
Result



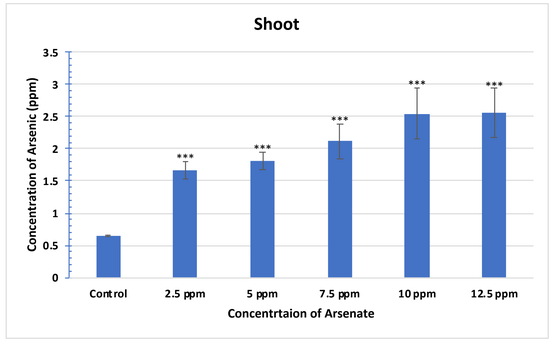
❖ **This graph shows the fresh weight of root tissue and shoot tissues**. No significant phenotypic effect with the highest arsenate concentration, 12.5 ppm was found.



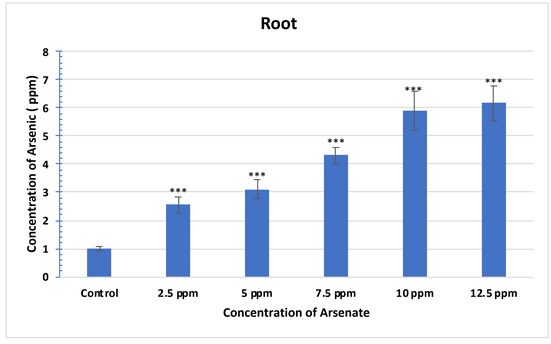
❖ **This graph shows the dry weight of root tissue and shoot tissues**. Compared to the control group, the shoot dry weight decrease significantly in 10 ppm; the root dry weight decrease significantly in 7.5 ppm, 10 ppm, and 12.5 ppm.



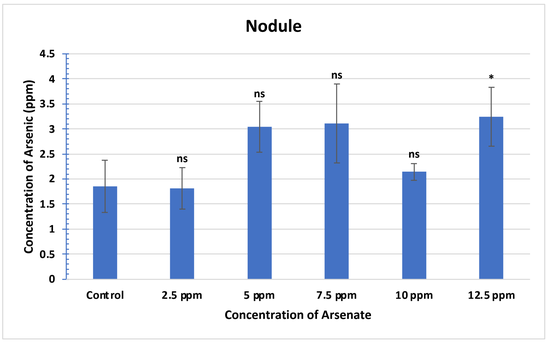
❖ **This graph shows the nodule dry and fresh weight**. Compared to the control group without arsenate treatment, the nodule dry weight and fresh weight both decrease significantly starting in 7.5 ppm, 10 ppm, and 12.5 ppm.



❖ **This graph shows that the shoot tissue of all As concentrations have significant increased compared to the control group.** The 12.5 ppm group have the highest arsenic concentration.



❖ **This graph shows that root tissue of the As treated group have significant increase compared to the control group.** The 12.5 ppm group have the highest arsenic concentration.



❖ **This graph shows that most of the As treated group have no significant increase compared to the control group**. Only the 12.5 ppm treatment group show significant increase compared to the control group.

Conclusion

- The soybean plants treated with arsenate did not show significant reduction in fresh and dry root & shoot biomass at these concentrations but showed significant reduction in nodule biomass at As concentration above 7.5 ppm.
- Treatments with increasing concentration of As in the soil resulted in higher total As accumulation in shoots and roots of the soybean plants but showed no significant increase in the arsenic accumulation in nodules, as compared to control.

Future Plan

After we found the appropriate arsenate concentration that can significantly affects the growth of soybean, we will apply this concentration to the full-scale experiment with the use of nano-sulfur treatment to counteract the As toxicity and preventing As accumulation in edible tissues and seeds. For investigation purpose, we will also use and compare different types of sulfur such as bulk-sulfur, nano-sulfur and sulfate to see if nano-sulfur is the most effective way to help the plant under arsenate stress.