Developing Cost Effective Biological Removal Technology for Selenium and Nitrate from Flue Gas Desulfurization (FGD) Wastewater from an Existing Power Generating Facility

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Outline

- Objective/Vision
- Background Information
- Team Description and Assignments
- Tasks
- Gantt Chart
- Milestones

Objective/Vison

The overall goal of our project is to investigate and determine a technically feasible and cost-effective process for designing photosynthetic organisms capable of sequestering Se and nitrates from FGD wastewater. To realize this goal, we have chosen to focus on the following 2 objectives:

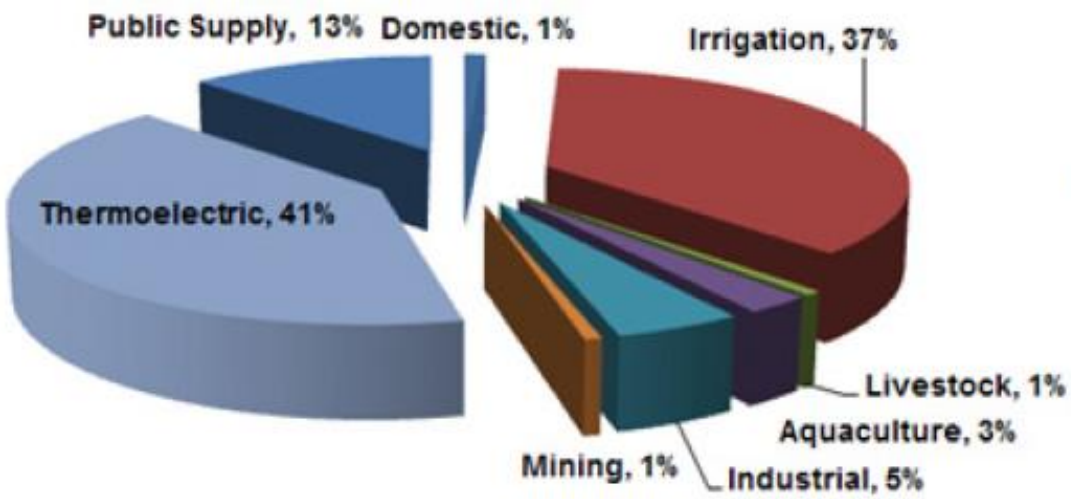
(1) Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater.

(2) Explore biotechnological strategies to increase sequestration of Se and nitrates in biomass to improve agricultural productivity.

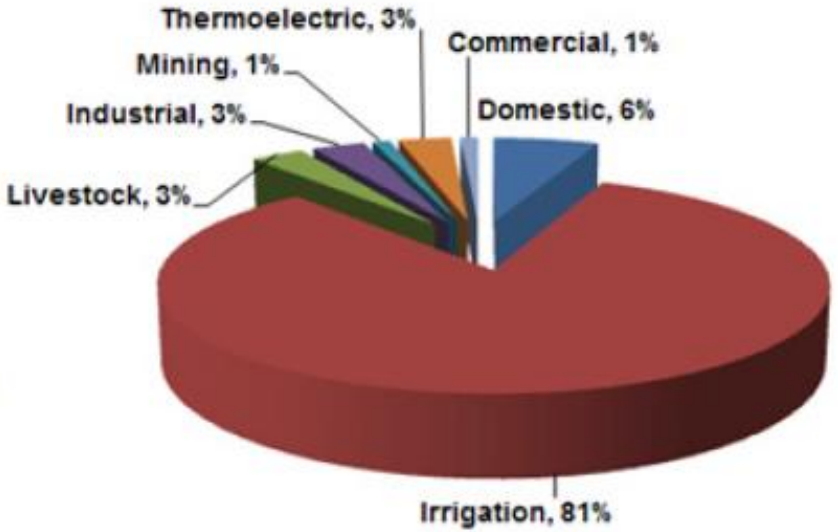
Academic objective: to enhance student hands-on experience and participation in STEM research and education

Background Information

Thermoelectric Power and Freshwater Use



U.S. Freshwater Withdrawal
USGS, Estimated Use of Water in the United States in 2005, USGS Circular 1344, 2009



U.S. Freshwater Consumption
USGS, Estimated Use of Water in the United States in 1995, USGS Circular 1200, 1998

http://www.netl.doe.gov/research/coal/crosscutting/water-management

Freshwater consumption is projected to increase further with the implementation of carbon capture technologies

Background Information

- Flue Gas Desulfurization (FGD) treatment is incorporated in most coal burning power generation plants to remove sulfur dioxide and various oxides of nitrogen by either wet/dry scrubbing.

- Large-scale coal fired thermoelectric plants in the USA consumes significant volumes of freshwater and generate considerable amounts of FGD wastewater.

- Wet scrubber blowdown often contains heavy metals (selenium, chromium, mercury etc.,), and nitrates in harmful concentrations.

- These constitute a major challenge for utilities and a major concern for environmental regulators.

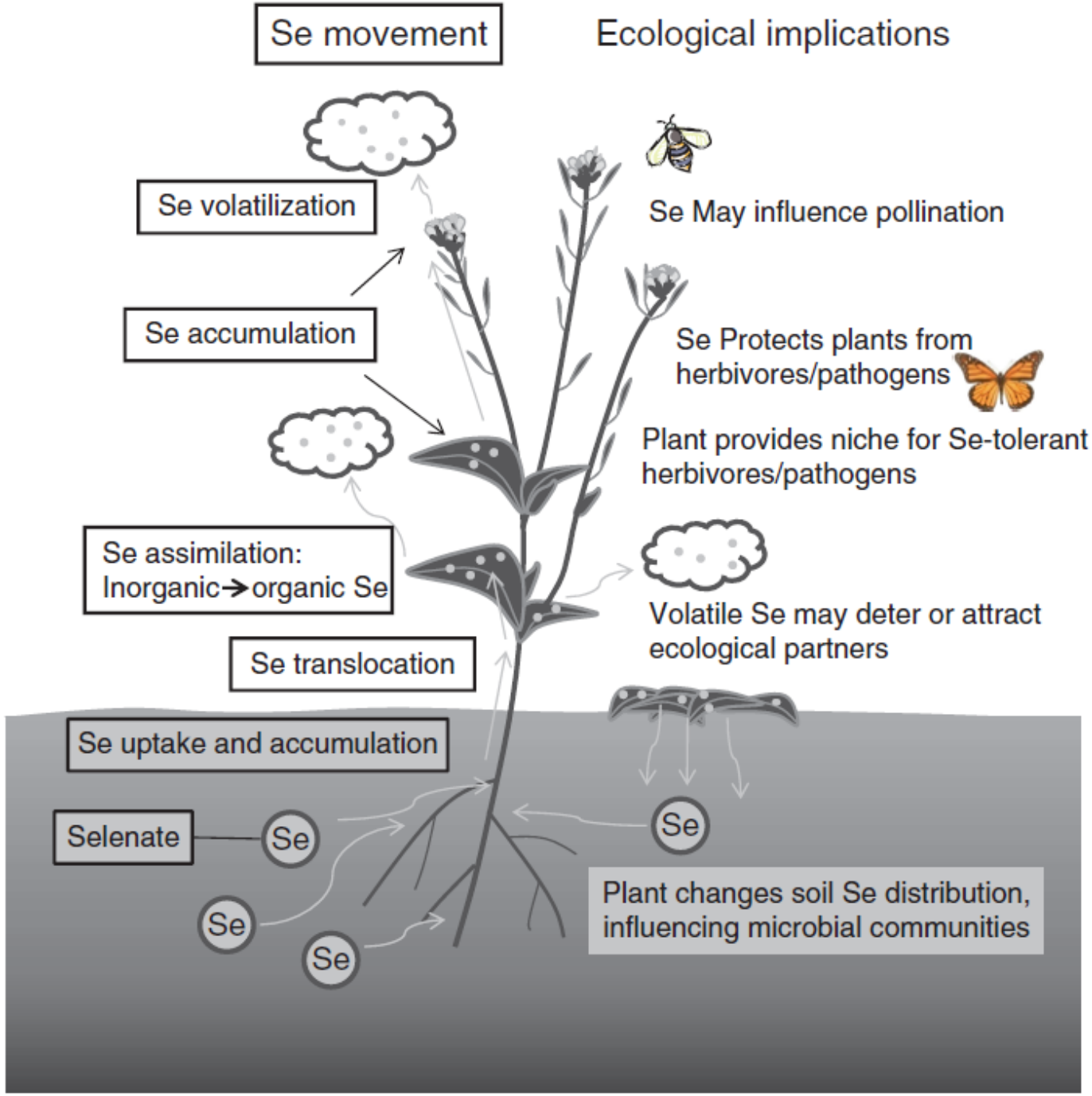
Background Information

- Removing Se and nitrates to ppb level is of particular challenge as conventional methods methods are generally not effective.
- Over the past two decades, industry has invested substantial resources in Se and nitrate removal technology (biological and chemical), achieving significant progresses.
- However, applications of these emerging technologies are considerably constrained by high cost, process complexity and other limitations.

Background Information

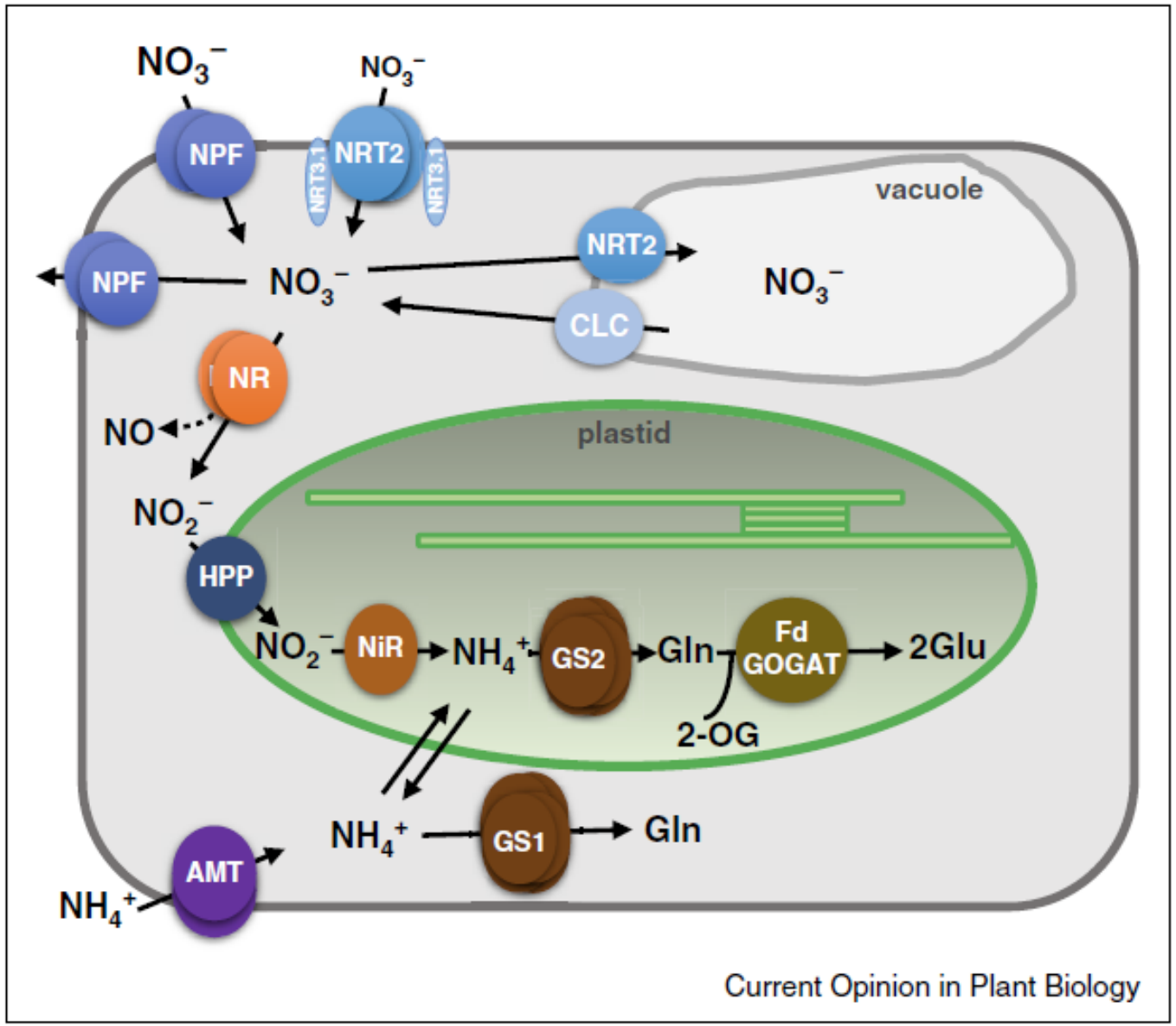
- Green algae and plants have the natural ability to degrade inorganic Se and nitrates.
- These organisms can be used in various ways to sequester Se and nitrates
- The best methods available for Se and nitrate reduction in FGD wastewater include sequestration in the harvestable biomass.
- Recent advances in molecular biology and biotechnology approaches to alter the capacity of plants to sequester inorganics have focused on both tolerance and accumulation.

Overview of the movement and metabolic conversion of Se by plants and their ecological implications



Pilon-Smits and Quinn in R. Hell and R.-R. Mendel (eds.), Cell Biology of Metals and Nutrients, Plant Cell Monographs 17, DOI 10.1007/978-3-642-10613-2_10, # Springer-Verlag Berlin Heidelberg 2010

Transport and enzymatic steps involved in primary nitrogen assimilation



Nitrate and ammonium are taken up by the root via specific transporters. Nitrate is reduced in the cytosol to nitrite by nitrate reductase (NR). A side reaction of NR produces nitrogen oxide (NO). Nitrite is then transported into the chloroplast by HPP transporters and reduced to ammonium by nitrite reductase (NiR). Ammonium is then incorporated into glutamate by the GS/GOGAT cycle.

Anne Krapp (2015), Current Opinion in Plant Biology, 25:115-122

Team Description and Assignments

- Principal Investigator. Dr. Sanjaya will oversee all the project-related activities in co-operation with collaborators.
- Undergraduate students will take part in our journal club and lab meetings, and they will be directly supervised and mentored by the PI and collaborators in a variety of research and analysis tasks.
- Technical partners. Liberty Hydro Inc. (South Charleston, WV), will assist with collecting and supplying FGD wastewater from coal-fired power plants. The Mid-Atlantic Technology, Research and Innovation Center (MATRIC; South Charleston, WV) will assist in part analysis of FGD wastewater and biomass.

Team Description and Assignments

- Bio-Chem Testing, Inc., (Hurricane, WV) will collaborate on the analysis of Se, nitrate, heavy metals, and other ions in FGD wastewater; and on analysis of biomass with CV-ICP-MS under EPA method 1631E, ICP-DRC-MS under EPA method 1638, IC-ICP-DRC-MS and DX-500, Dionex.

Task Description

Objective 1.0 Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater

Task 1.1. Characterize the transcriptome signature of photosynthetic organisms exposed to FGD wastewater

Task 1.2. Perform post-sequence analysis and qRT-PCR analysis

Task 1.3. Perform functional analysis of candidate genes in model system

- Short generation time-6-8 weeks from seed-seed
- Small size
- Wider adaptability
- Self-fertilization
- Susceptibility to Agrobacterium infection
- Small genome size -125 million base pairs
- Large collection of T-DNA

Task Description

Objective 2. *Explore biotechnological strategies to manipulate Se and nitrate metabolism for increased agricultural production*

Task 2.1. Generate transgenic *Arabidopsis* lines expressing Se/nitrate transporter alone or in combination

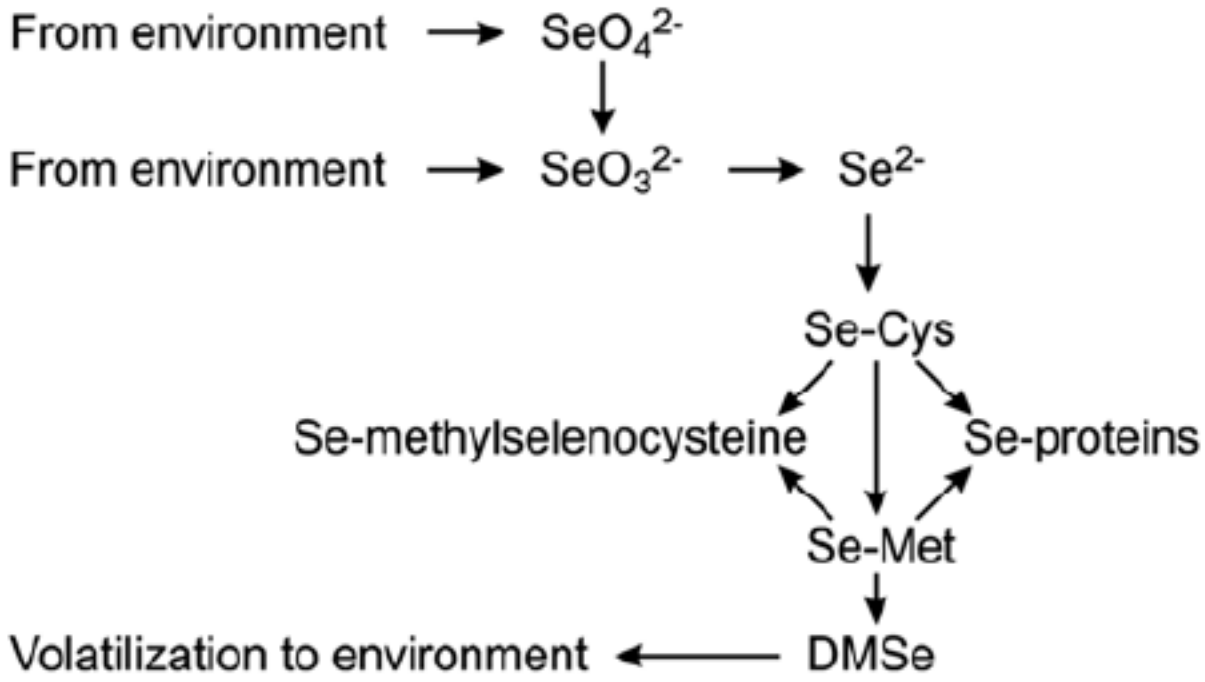


Fig. 1 Schematic representation of the main steps of Se-metabolism in plants (adapted from Dumont *et al.* 2006).

Abbreviations: DMSe, Dimethylselenide; **SeCys**, selenocysteine; **SeMet**, selenomethionine

Task Description

Task 2.2. Perform hydroponic/soil cultivation of algae, Duckweed and transgenic Arabidopsis in FGD wastewater

Task Description

Task 2.3. Conduct Se, nitrate, other heavy metals and metabolite analysis

Task 2.4. Analyze gene expression of transgenic Arabidopsis lines overexpressing transporters

Objective/Task	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4	Y3 Q1	Y3 Q2	Y3 Q3	Y3 Q4
Objective 1: Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater												
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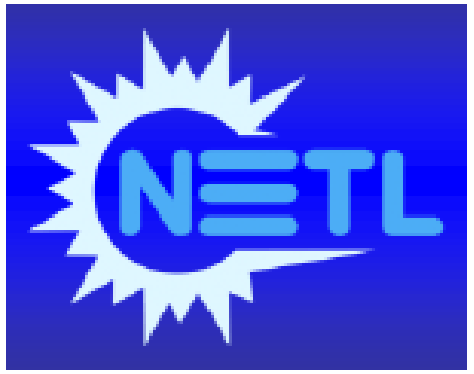
Milestone Log						
Objective/Task	Fall Y1 (Q1 & Q2)	Spring-Summer Y1 (Q3 & Q4)	Fall Y2 (Q1 & Q2)	Spring-Summer Y2 (Q3 & Q4)	Fall Y3 (Q1 & Q2)	Spring-Summer Y3 (Q3 & Q4)
Project development and agreement with the FPM	X					
Undergraduate Student Recruitment	X		X		X	
Undergraduate training and development of students' Independent Research Projects		X		X		X
Objective 1: Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater	X	X	X	X		
Task 1.1. Characterize the transcriptome signature of photosynthetic organisms exposed to FGD wastewater	X	X	X	X		
Task 1.2. Perform post-sequence analysis and qRT-PCR analysis	X	X	X	X		
Task 1.3. Perform functional analysis of candidate genes in model system		X	X	X	X	X
Objective 2. Explore biotechnological strategies to manipulate Se and nitrate metabolism for increased agricultural production	X	X	X	X	X	X
Task 2.1. Generate transgenic Arabidopsis lines expressing Se/nitrate transporter alone or in combination		X	X	X	X	X
Task 2.2. Perform hydroponic/soil cultivation of algae, Duckweed and transgenic Arabidopsis in FGD wastewater			X	X	X	X
Task 2.3. Conduct Se, nitrate, other heavy metals and metabolite analysis			X	X	X	X
Task 2.4. Analyze gene expression of transgenic Arabidopsis lines overexpressing transporters				X	X	X
Students/PI present at the ASPB/GRC on plant lipids conference		X		X		X
Students/PI present at local area schools		X		X		X
Students/PI prepare and submit manuscripts			X		X	X
New grant application preparation and submission			X		X	

Acknowledgments



Thank you for your Attention!