DOE NETL Project Review Meeting, April 10 – 12, 2018

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
- Background Information
- Results
- Future Works

Objectives

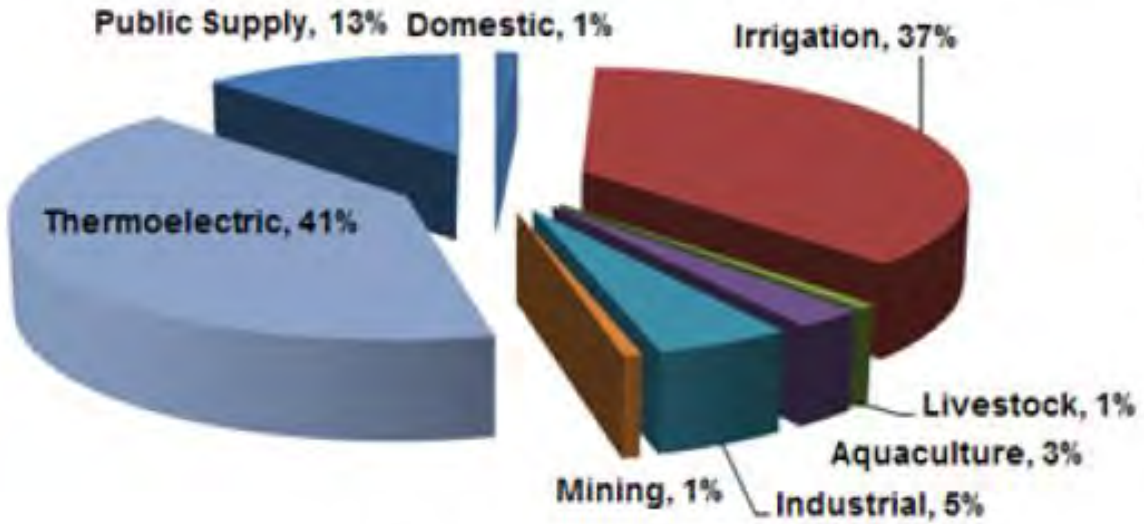
The overall goal of our project is to investigate and determine a technically feasible and cost-effective process for designing photosynthetic organisms capable of sequestering Se and nitrates from FGD wastewater. To realize this goal, we have chosen to focus on the following 2 objectives:

(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

Thermoelectric Power and Freshwater Use



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

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.

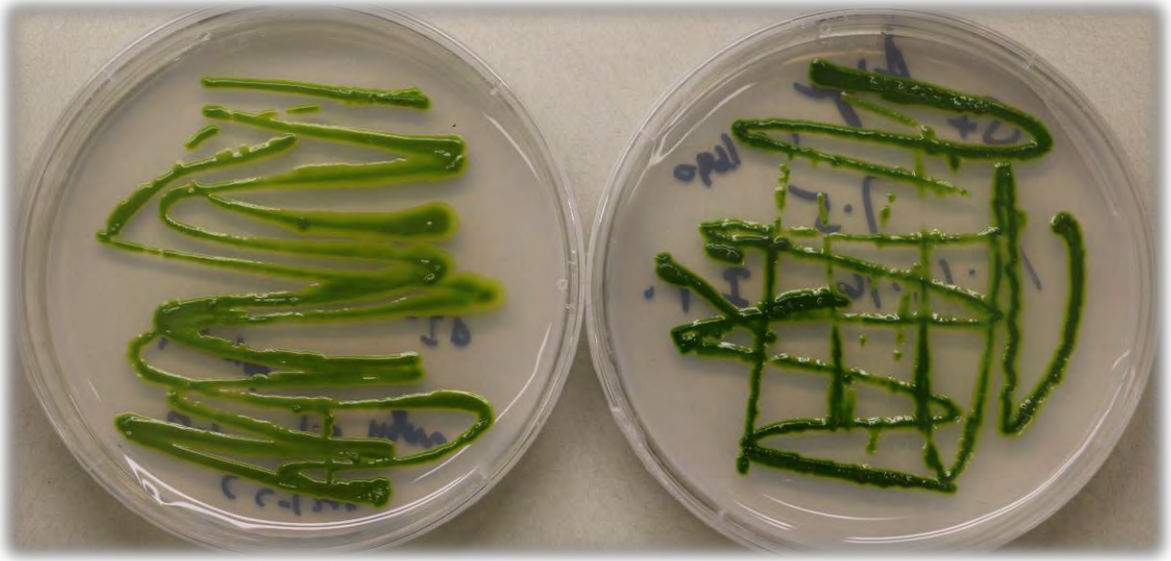
- Wet scrubber blowdown often contains heavy metals (selenium, chromium, mercury etc.,), and nitrates in harmful concentrations.

- 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 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.

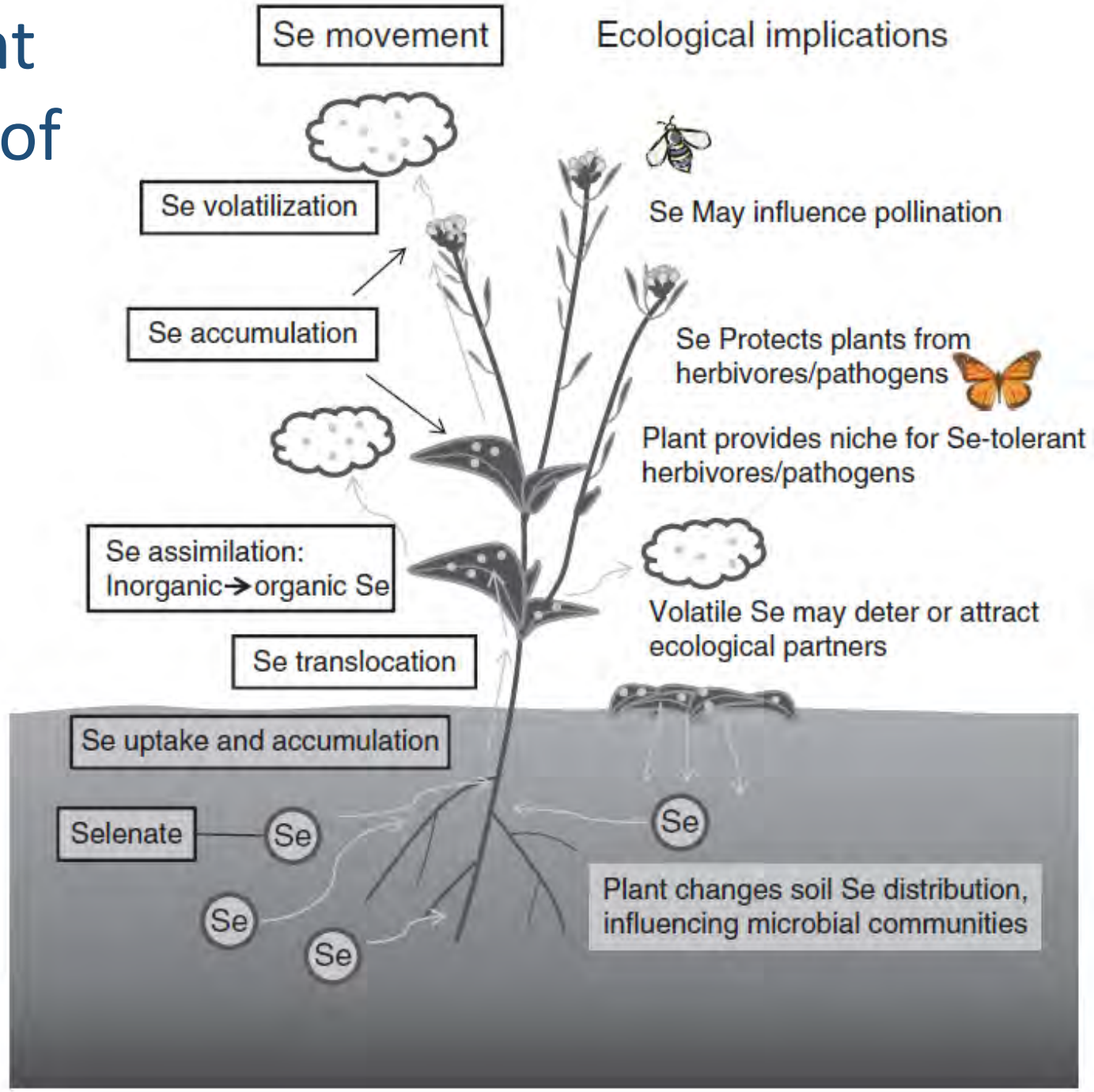
Green algae and plants have the natural ability to degrade inorganic Se and nitrates



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.

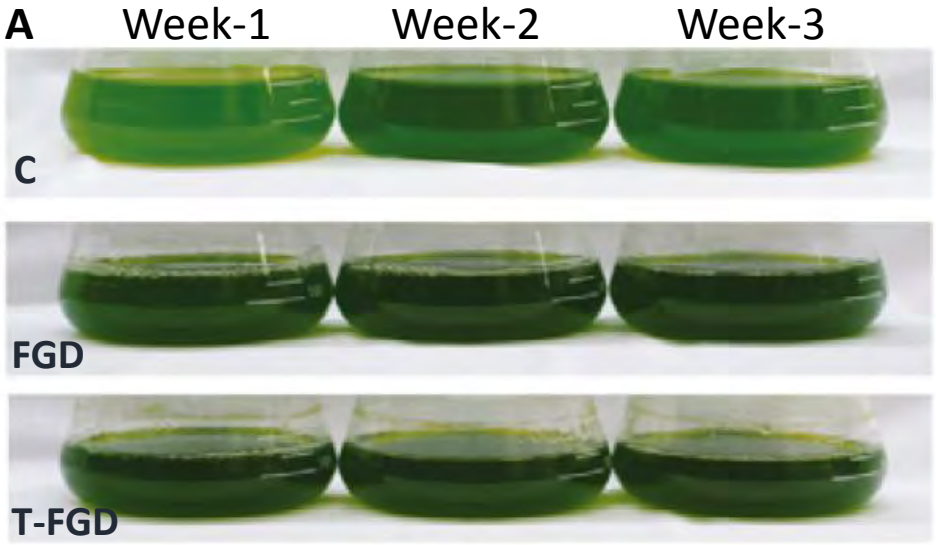
Overview of the movement and metabolic conversion of Se by plants and their ecological implications

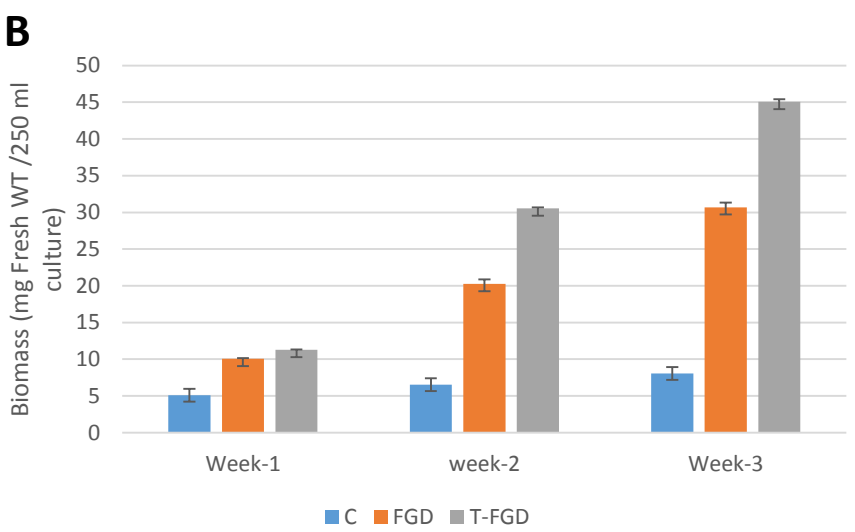


Pilon-Smits and Quinn in R. Hell and R.-R. Mendel (eds.), Cell Biology of Metals and Nutrients, Plant Cell Monographs 17, DOI 10.1007/978-3-642-10613-2_10, # Springer-Verlag Berlin Heidelberg 2010

Initiated collaboration with John Amos power plant through Liberty Hydro and obtained treated and untreated FGD samples

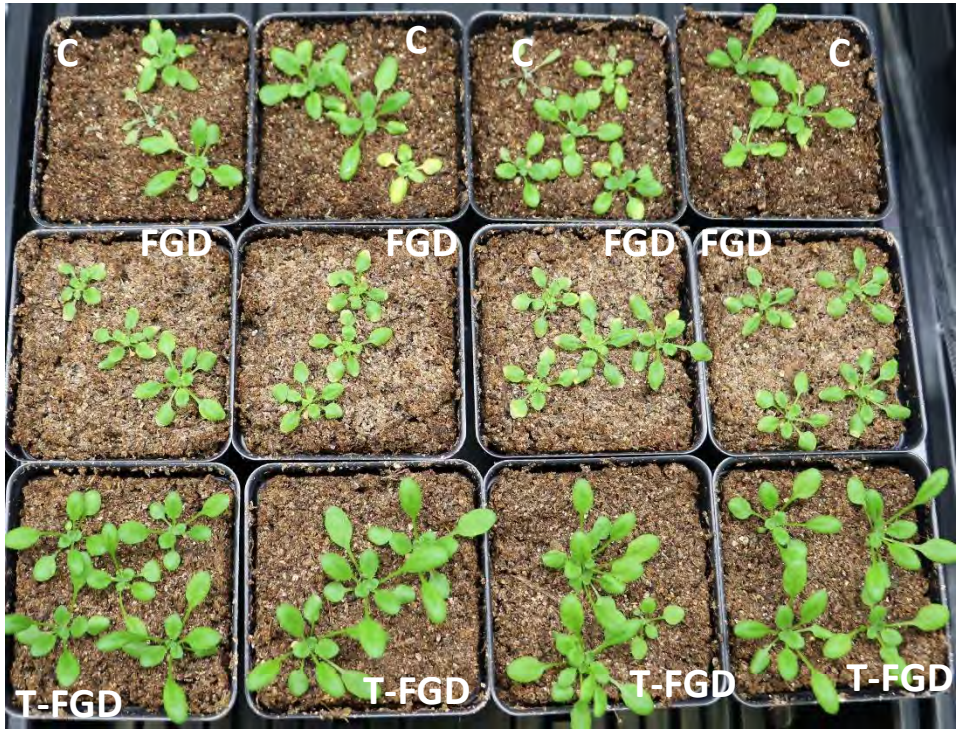
Effect of FGD wastewater on freshwater algae biomass

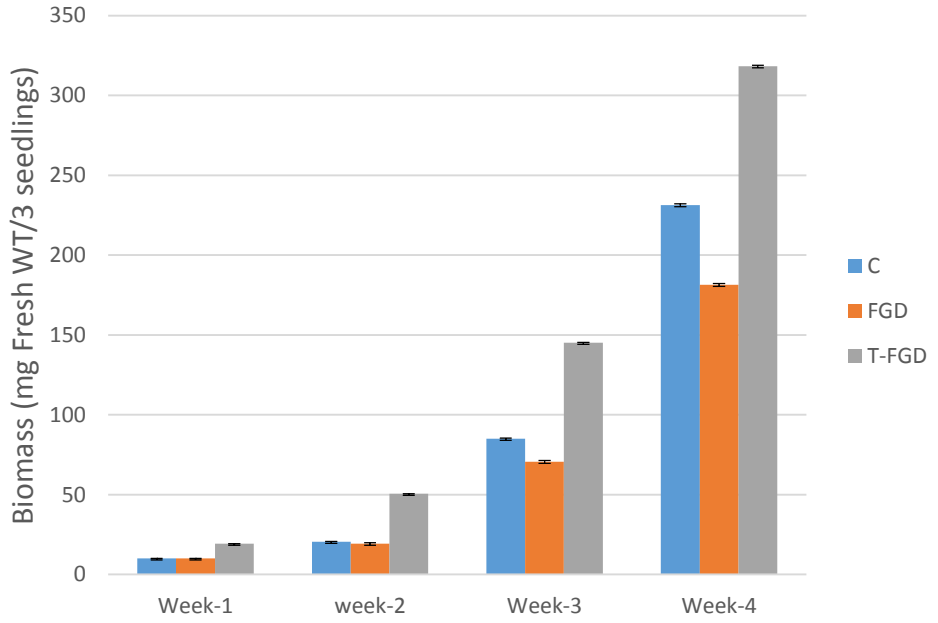




Growth of Algae in culture medium supplemented with FGD and T-FGD wastewater for week-1 to 3; B. Algae biomass measurement for week-1 to 3, data were derived from three replications. Data indicate that algal biomass growth rate was higher in medium supplemented with FGD and T-FGD wastewater. C: Control; FGD: Flue gas desulfurization wastewater; T-FGD: Physical/Chemical treated flue gas desulfurization wastewater.

Effect of FGD wastewater on plant biomass (*Arabidopsis thaliana*)



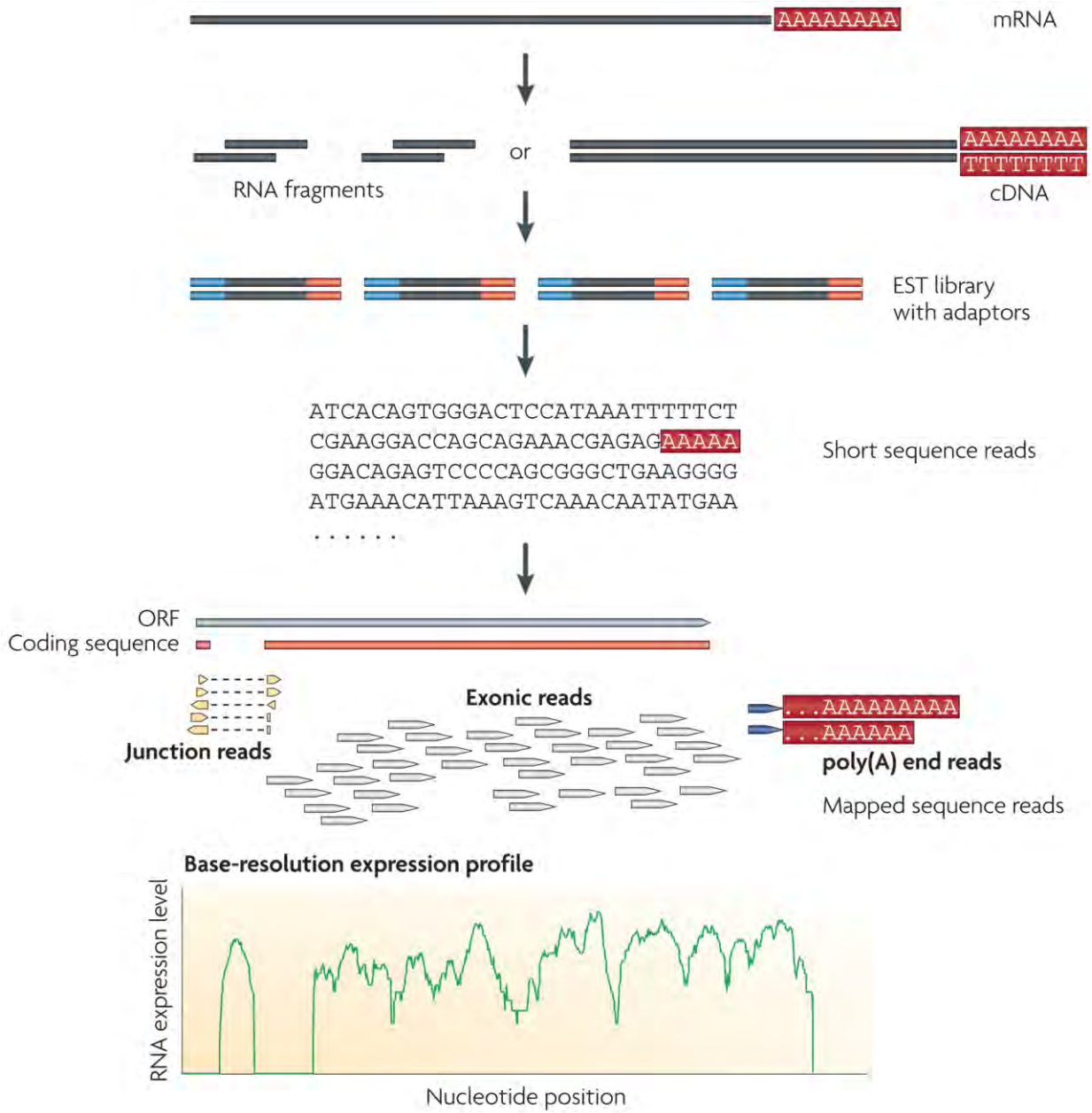


A. Growth of Arabidopsis in soil watered with FGD and T-FGD wastewater for week-1 to 3; B. Plant biomass measurement for week-1 to 3, data were derived from three replications. Data indicate that plant biomass growth rate was higher in plants watered with T-FGD wastewater. C: Control; FGD: Flue gas desulfurization wastewater; T-FGD: Physical/Chemical treated flue gas desulfurization wastewater.

Effect of FGD wastewater on Duckweed biomass

Control FGD T-FGD

Perform post-sequence analysis and qRT-PCR analysis



Wang et al., 2009. *Nat Rev Genet*; 10(1): 57–63

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

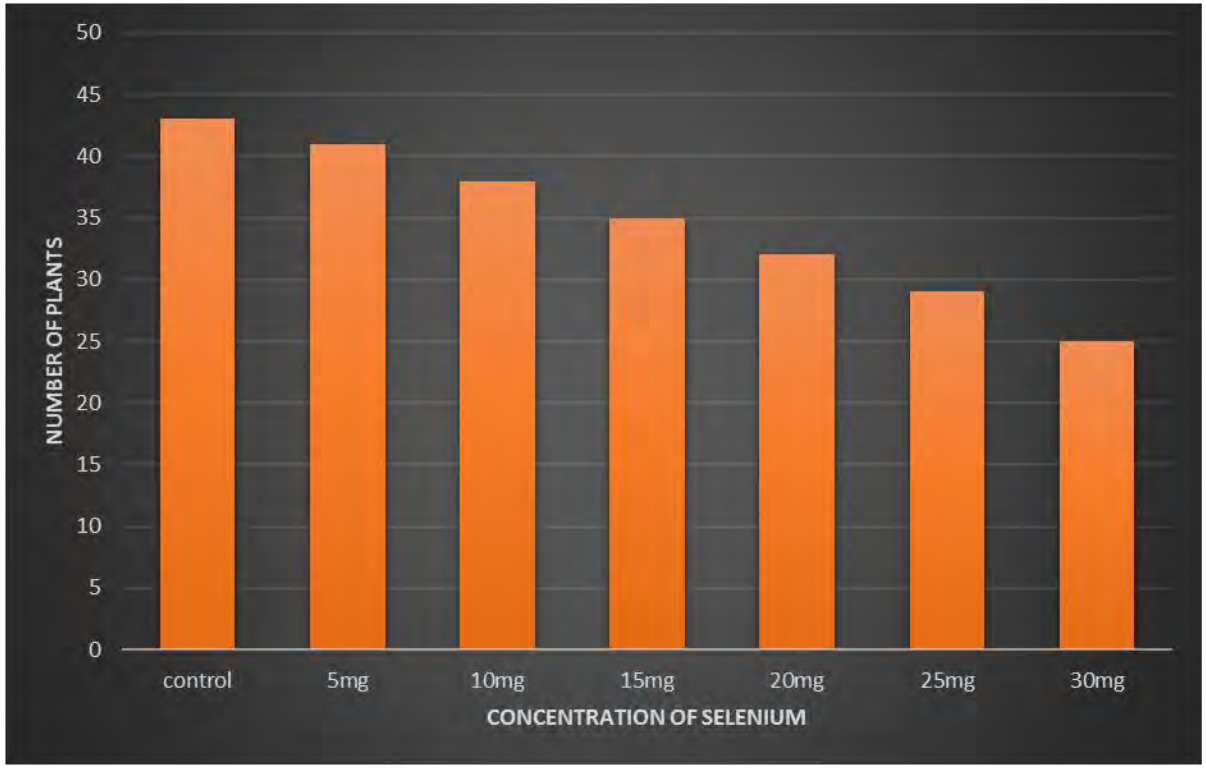
Effect of Selenium on Spirodella and Lemna Growth

Control 5mg/L 10mg/L 15mg/L 20mg/L 25 mg/L 30mg/L

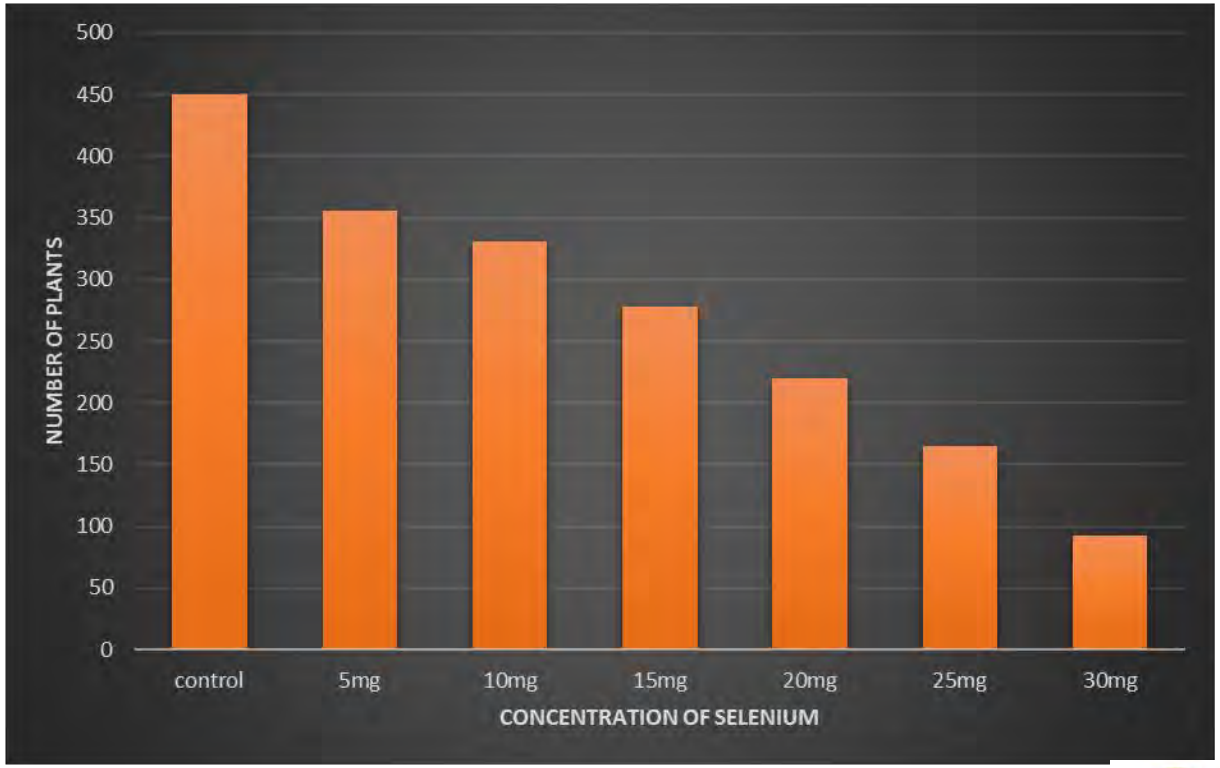
Control 5mg/L 10mg/L 15mg/L 20mg/L 25 mg/L 30mg/L

Effect of Selenium on Spirodella Growth

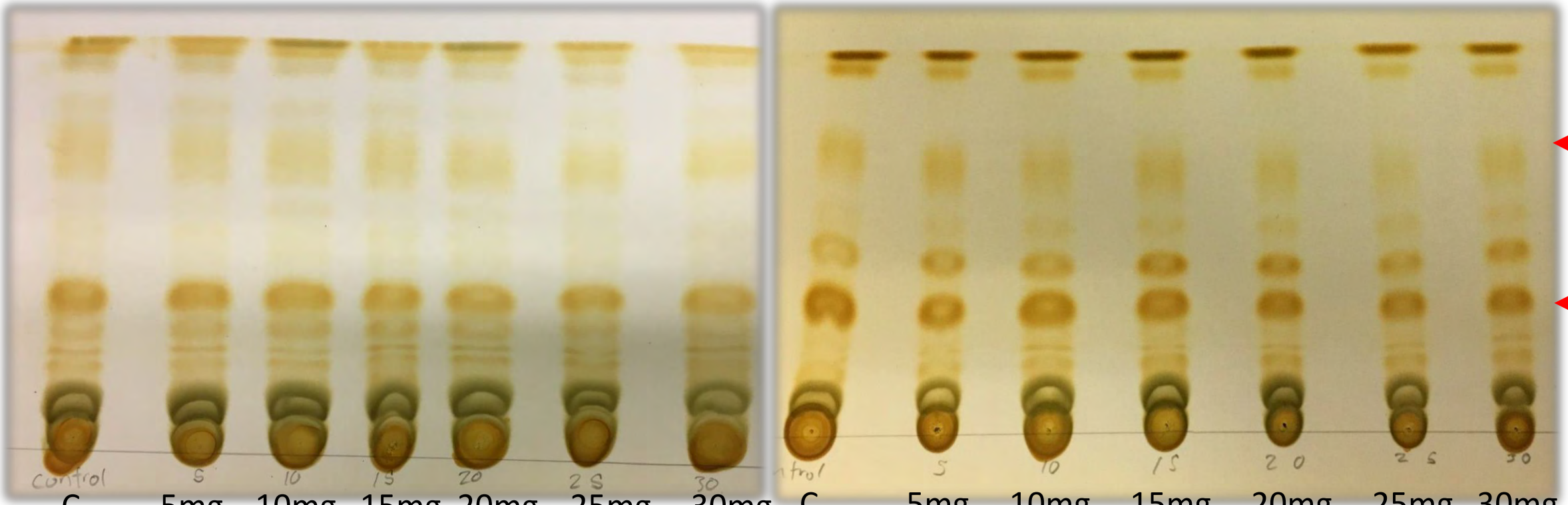
After 10 days of growth



After 20 days of growth



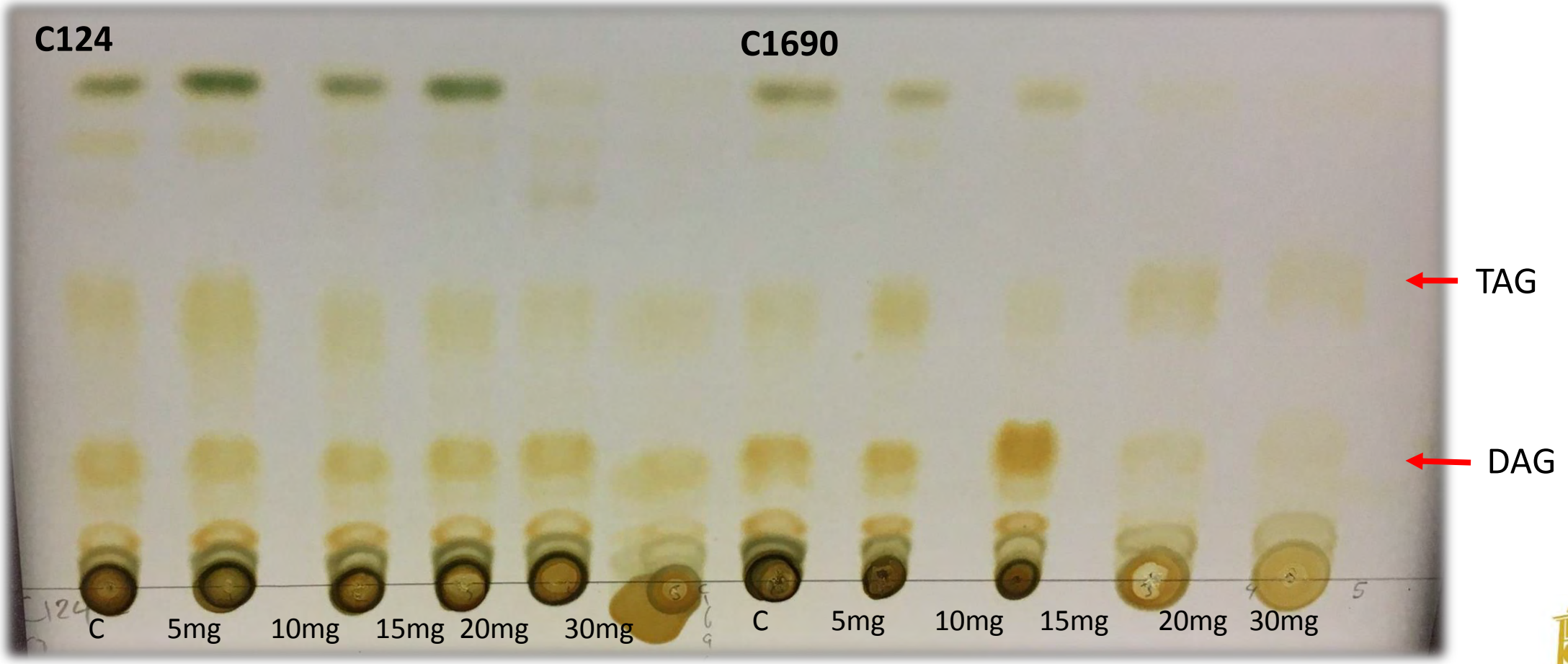
Effect of Selenium on Lipid Production



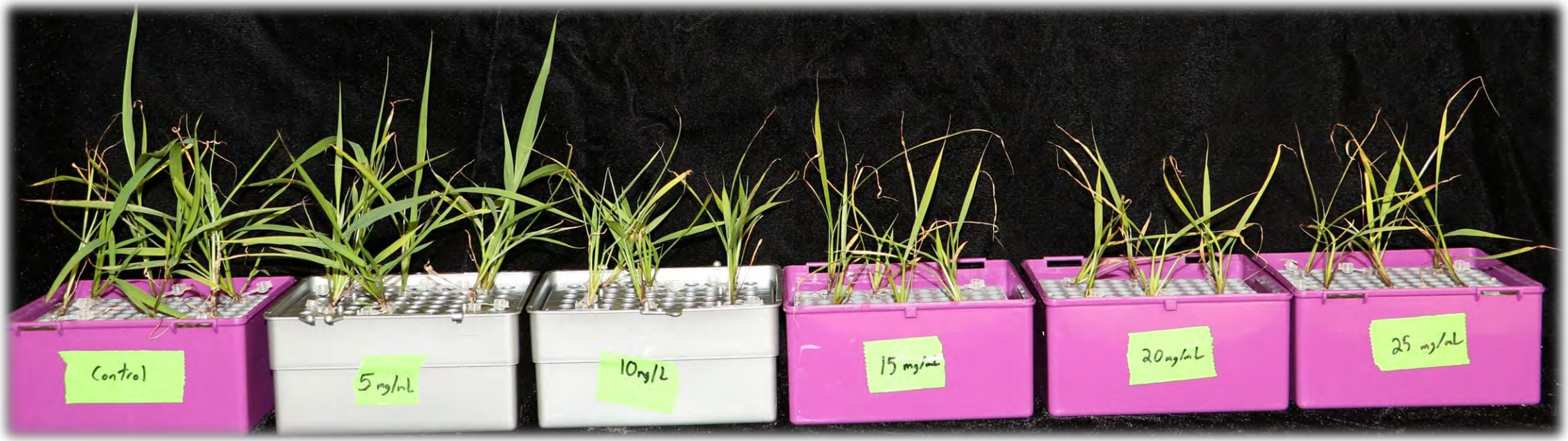
SPIRODELLA

LEMNA

Effect of Selenium on Lipid Production in Algae

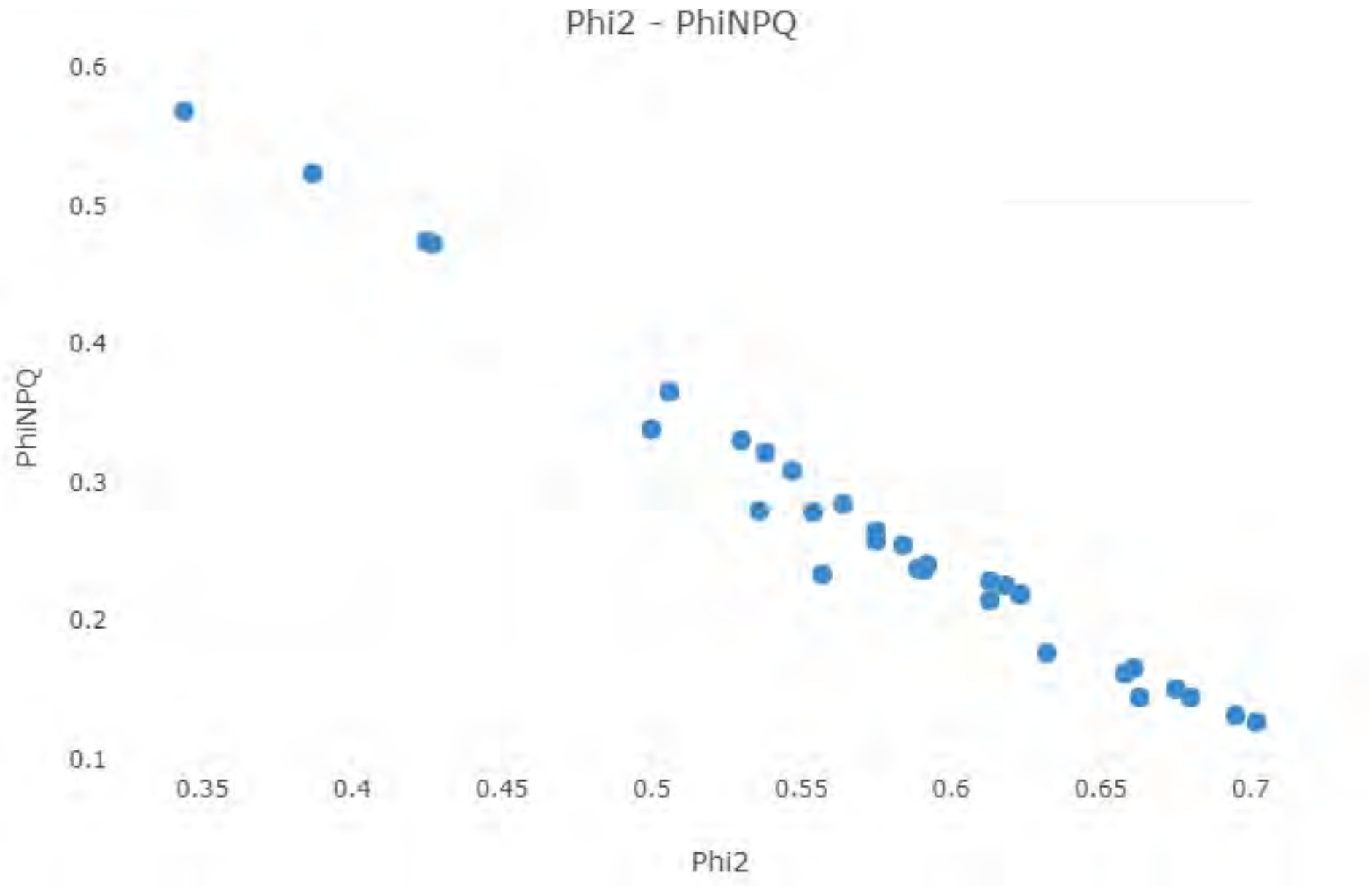


Establishment of Selenium on Setaria

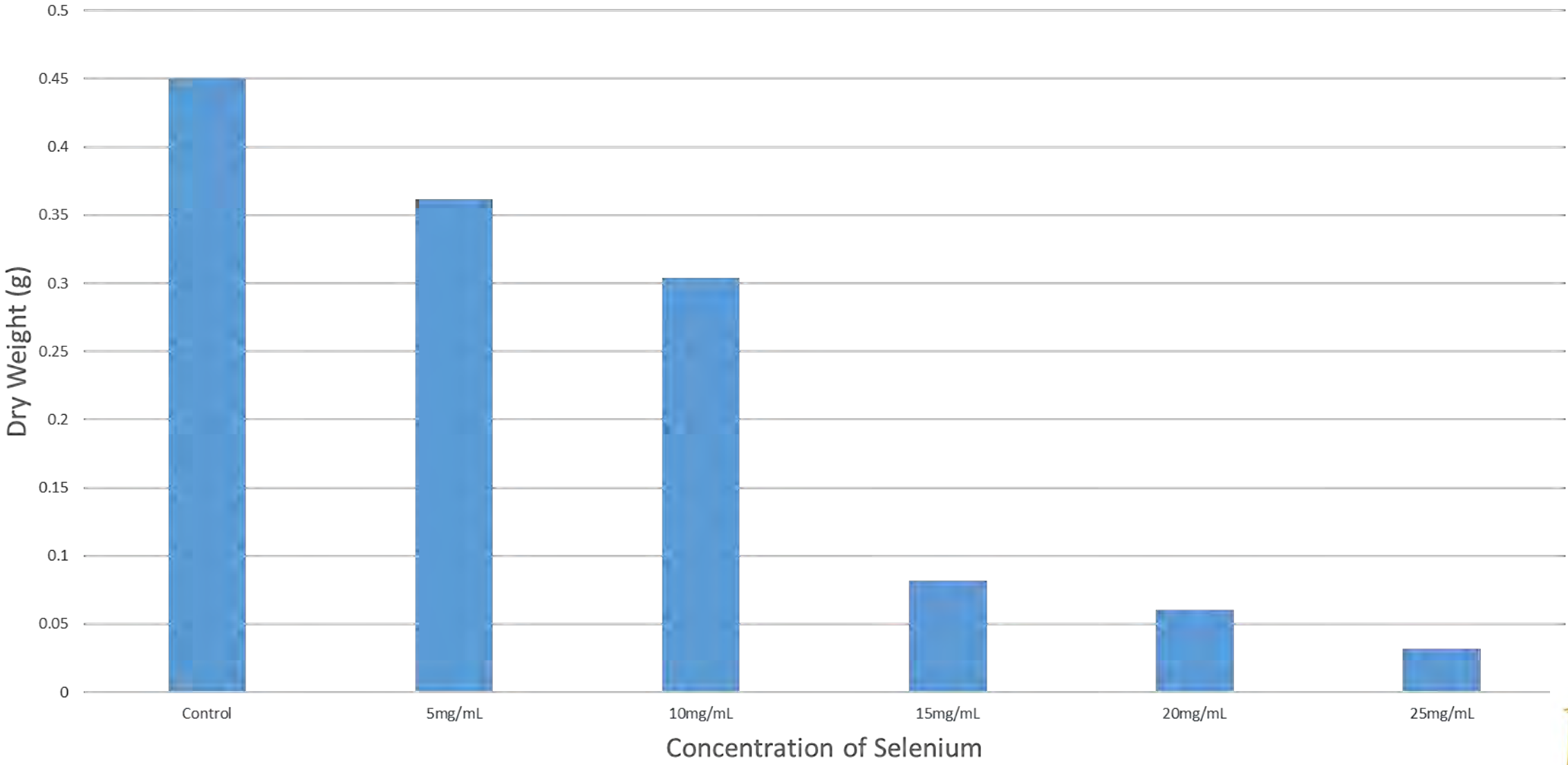


- Established a hydroponics system to test effects of individual chemicals present in FGD wastewater.
- Two week old hydroponically established plants were then exposed to selenium in different concentrations from 5mg/mL up to 25mg/mL
- Treatments ran for four weeks, rate of photosynthesis data and final biomass were calculated.

Selenium Treatment Inhibits Photosynthesis



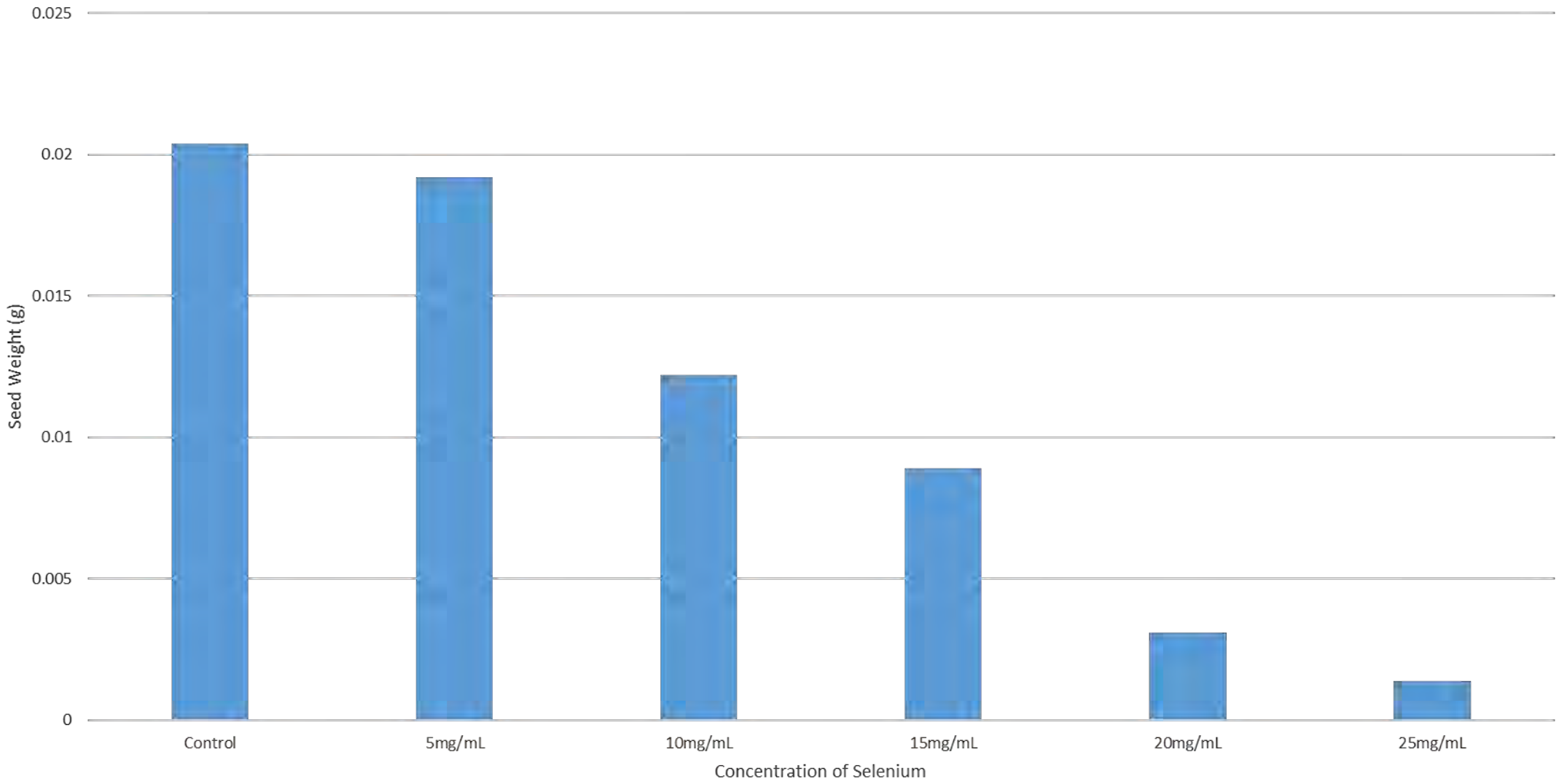
Effect of Selenium on Aerial Biomass



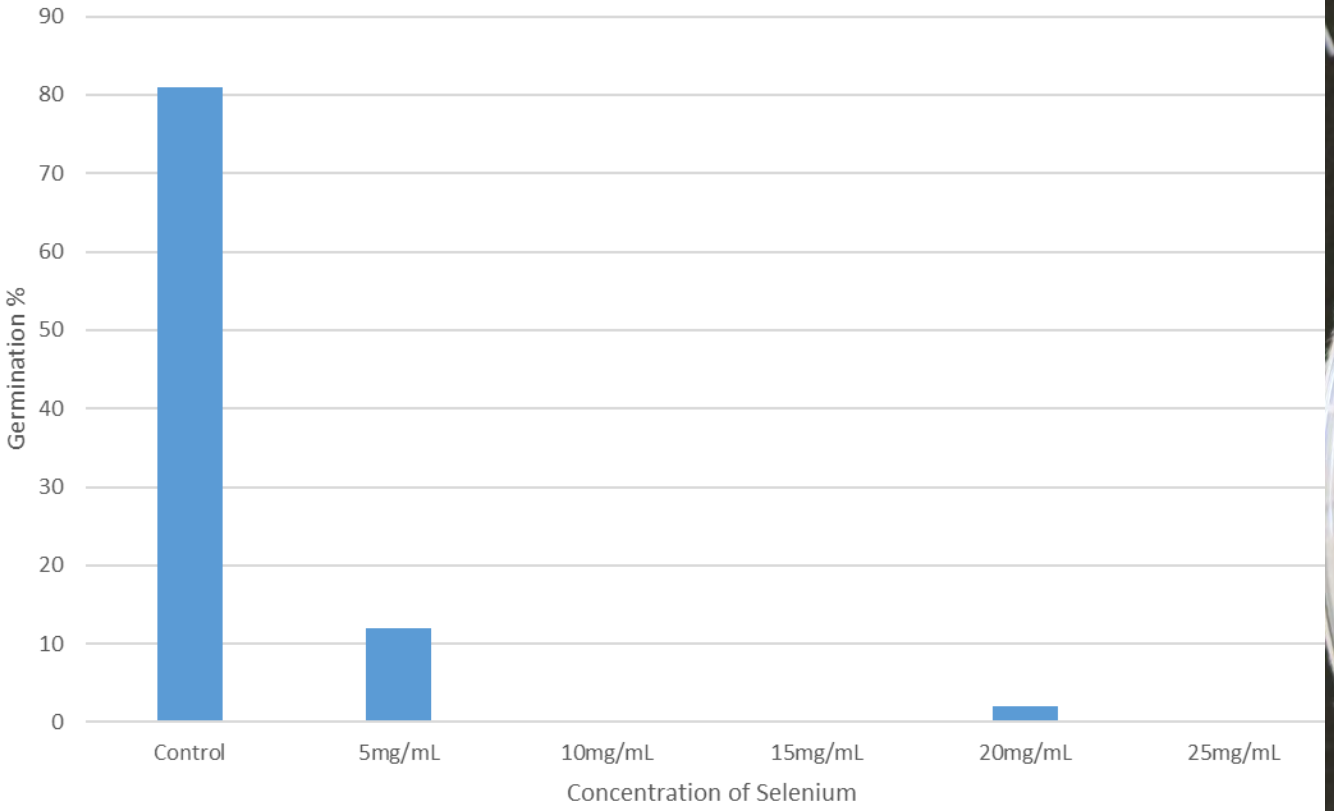
Effect of Selenium on Arabidopsis

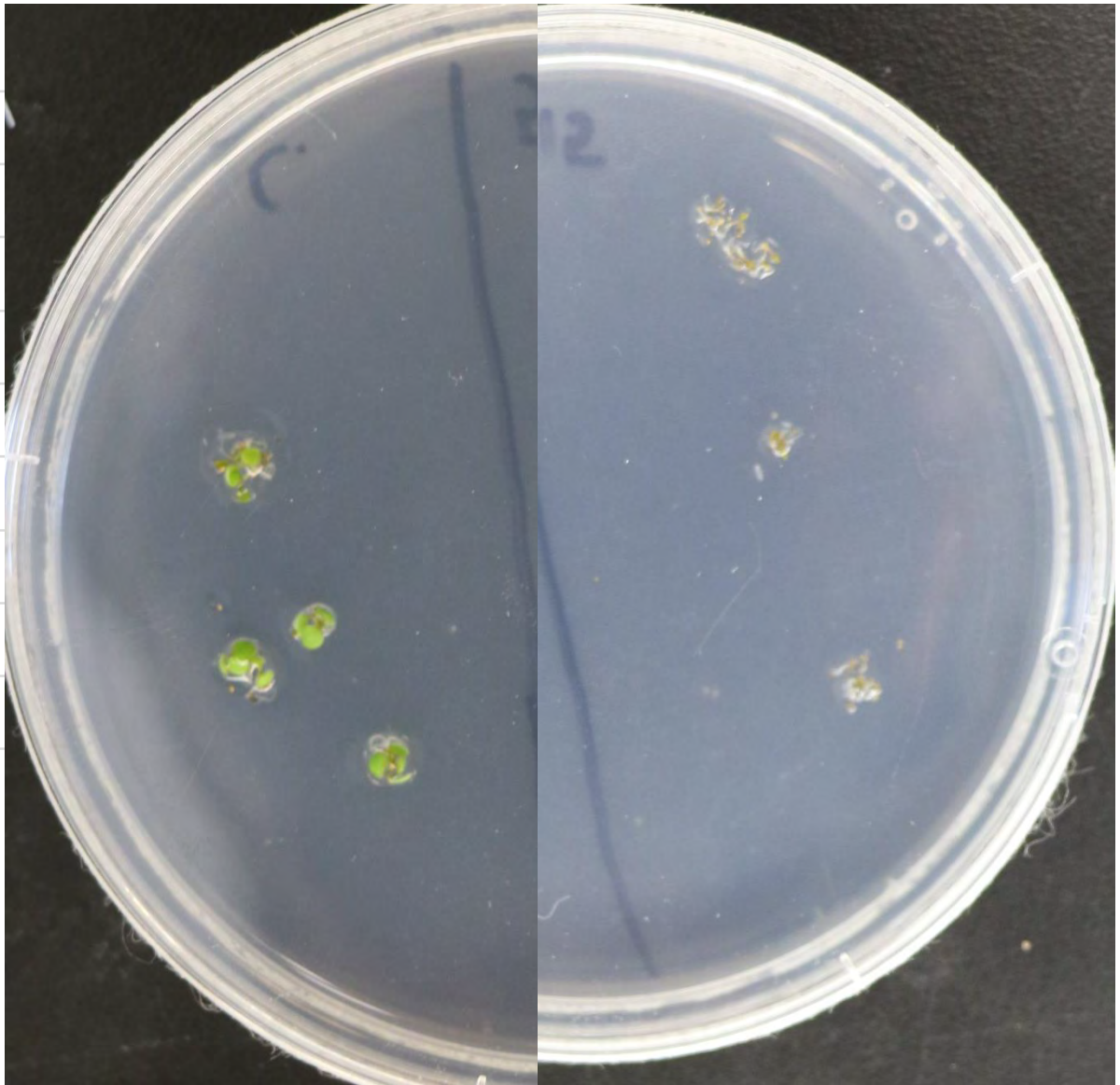
- Treatments ran for four weeks, photosynthesis data was collected, and biomass was harvested and weighed. Seeds were collected, weighed, and tested for germination viability.

Effect of Selenium on Seed Production

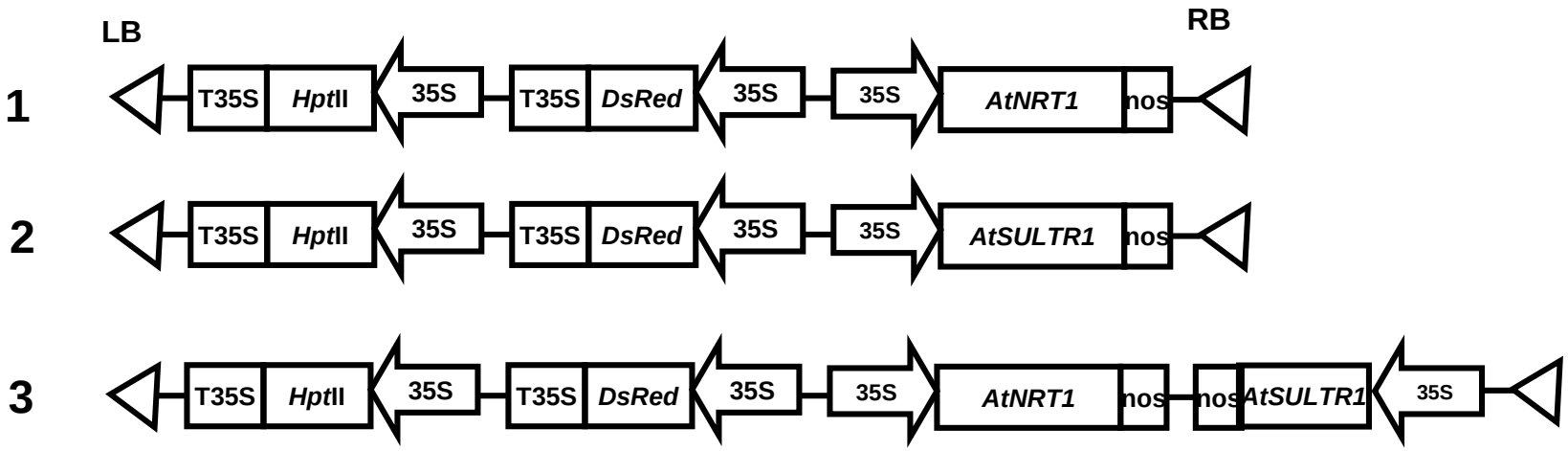


Selenium Treatment Negatively Effects on Arabidopsis Seed Development and Germination





Schematic representation of binary vectors used for transgenic plants establishment



Current status:

T1 generation plants are growing…

Learning Water Quality in a Class Room

Oral presentation in WVSU SURE symposium, 2017
Poster presentation in 1890 ARD symposium, 2017
Oral presentation in ASPB symposium, 2017

Studying the Effect of Water on Plant Physiology

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Collaboration

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Liberty Hydro, Inc.,

Bio-Chem Testing, Inc.,

MICHIGAN STATE UNIVERSITY

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