DOE NETL Project Review Meeting, April 09 – 11, 2019

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

- Project Description and Objectives
- Background Information
- Project Update
- Preparing Project for Next Steps
- Concluding Remarks

Objectives

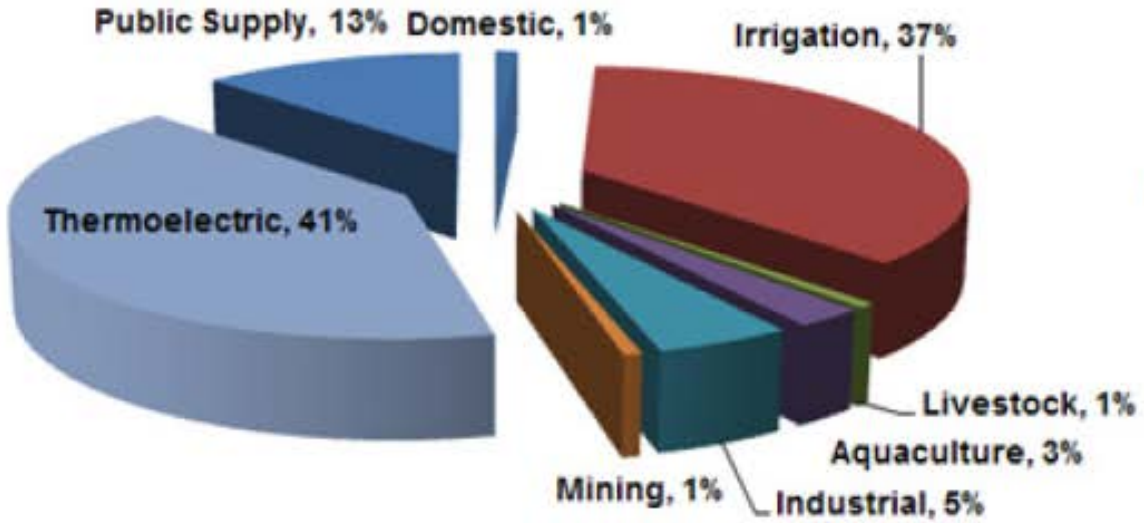
The overall goal of our project is to investigate and determine a technically feasible and cost-effective process for designing photosynthetic organisms capable of sequestering Se and nitrates from FGD wastewater. To realize this goal, we have chosen to focus on the following 2 objectives:

(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

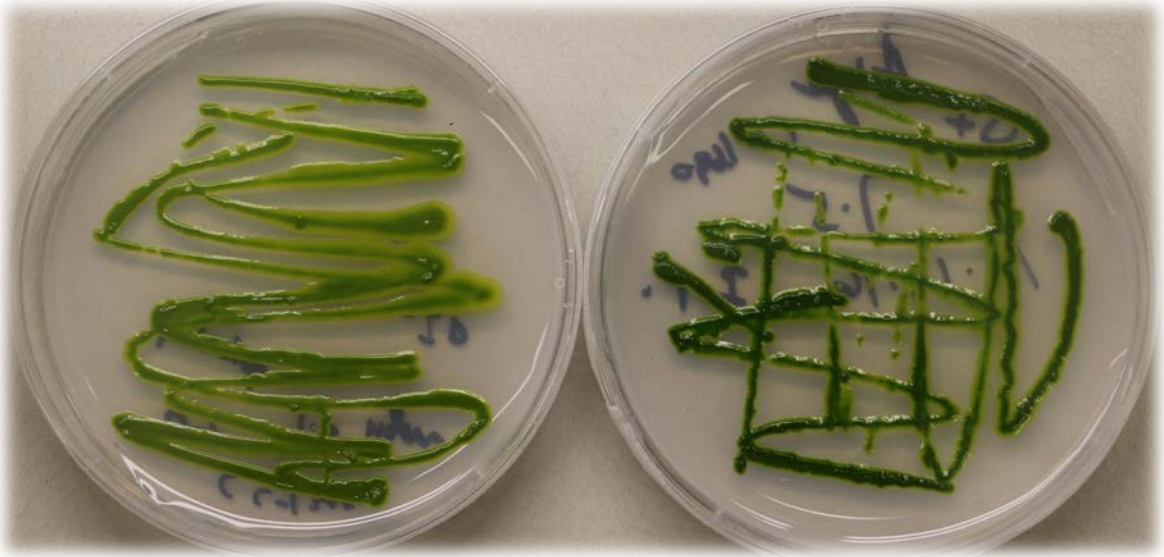
- Flue Gas Desulfurization (FGD) treatment is incorporated in most coal burning power generation plants to remove sulfur dioxide and various oxides of nitrogen by either wet/dry scrubbing.

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

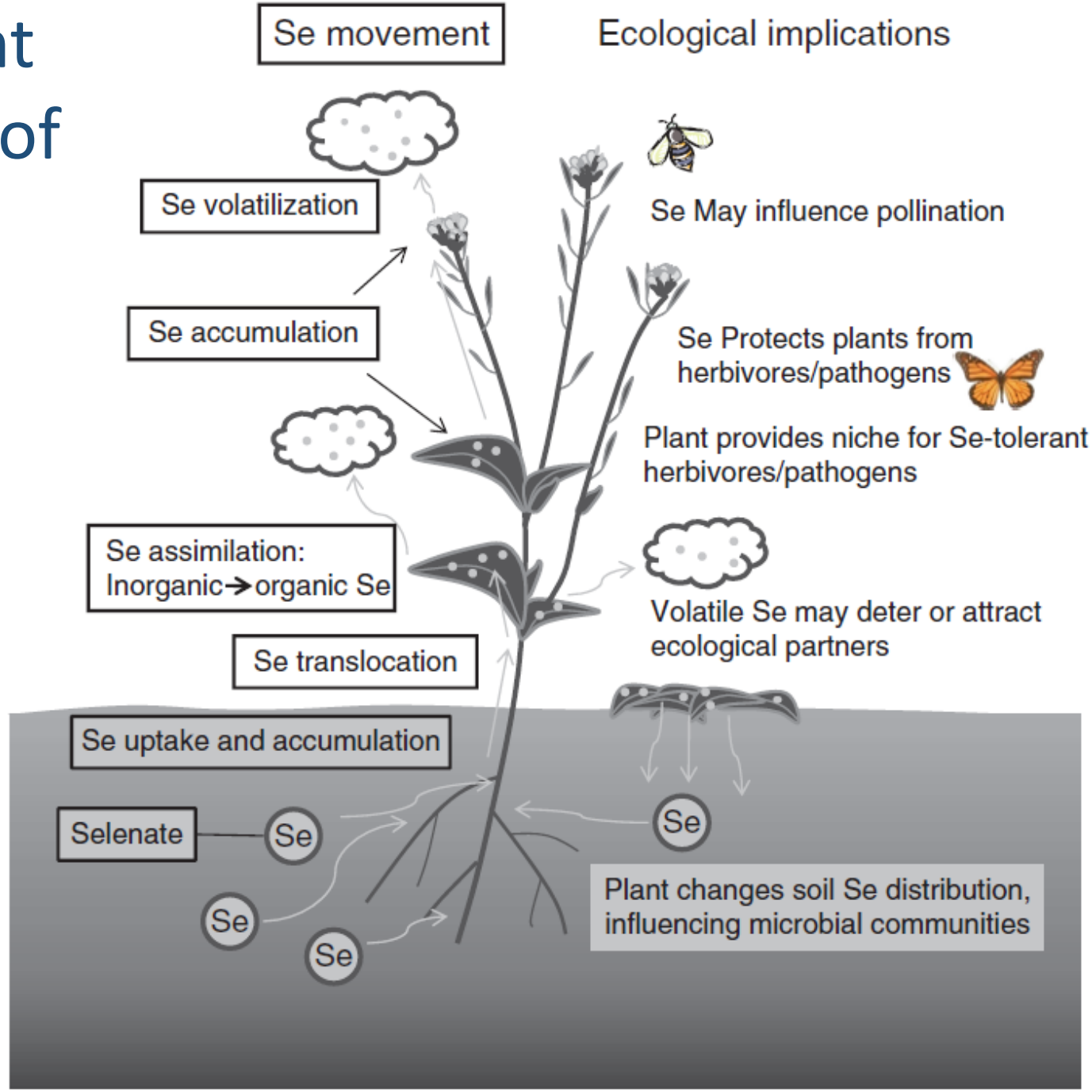
- Wet scrubber blowdown often contains heavy metals (selenium, chromium, mercury etc.,), and nitrates in harmful concentrations.

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

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



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

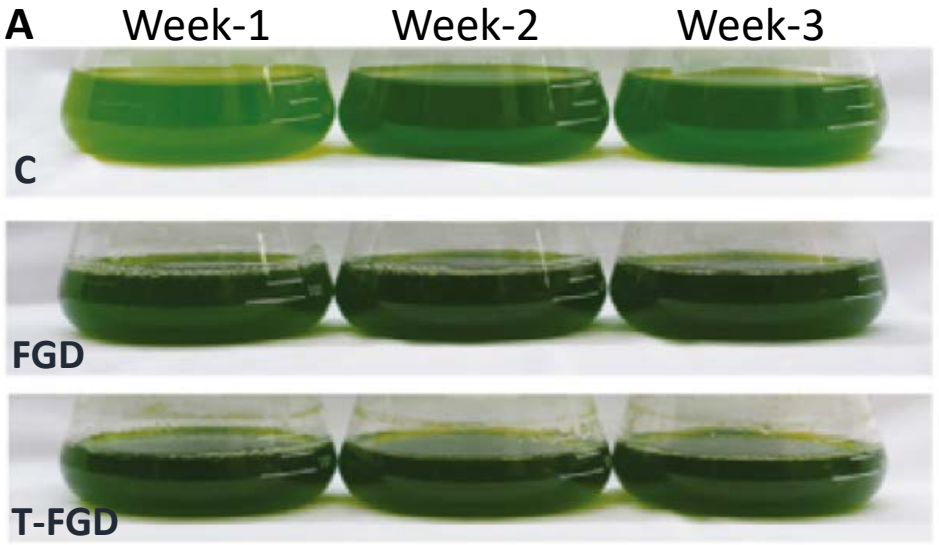


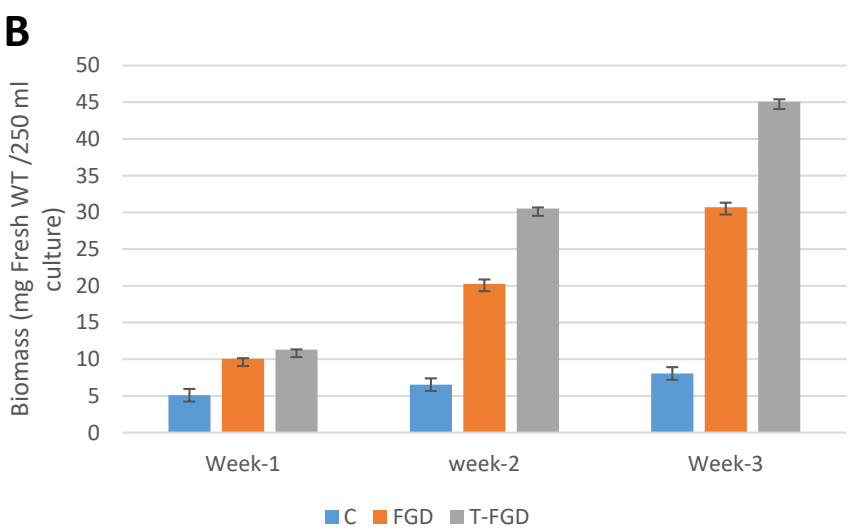
Pilon-Smits and Quinn in R. Hell and R.-R. Mendel (eds.), Cell Biology of Metals and Nutrients, Plant Cell Monographs 17, DOI 10.1007/978-3-642-10613-2_10, # Springer-Verlag Berlin Heidelberg 2010

Project Update

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

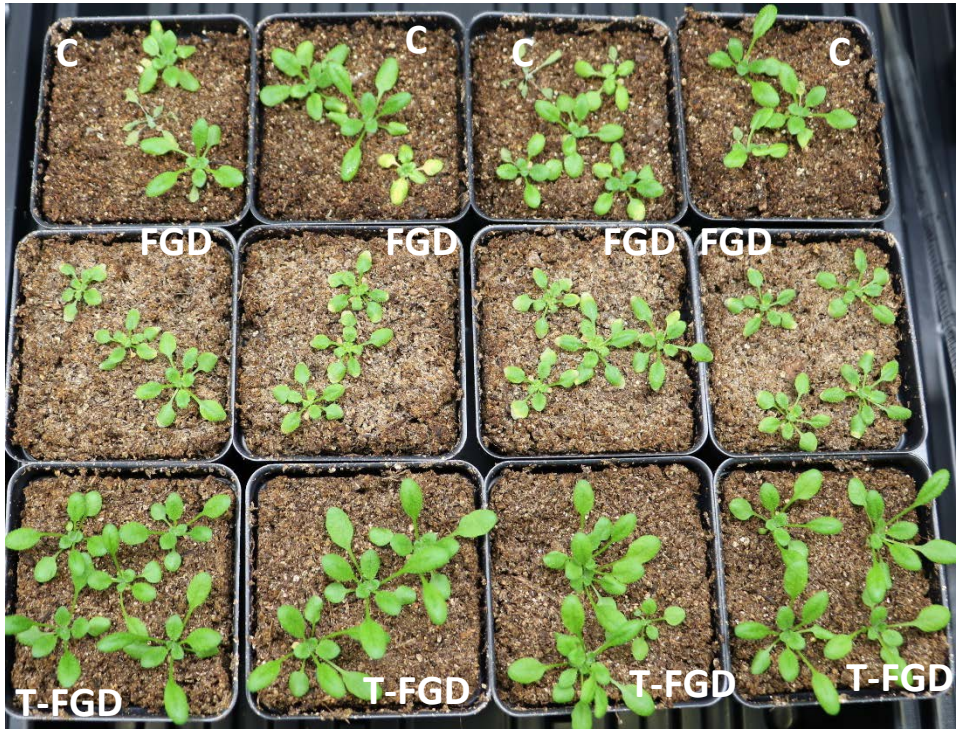
Effect of FGD wastewater on freshwater algae biomass

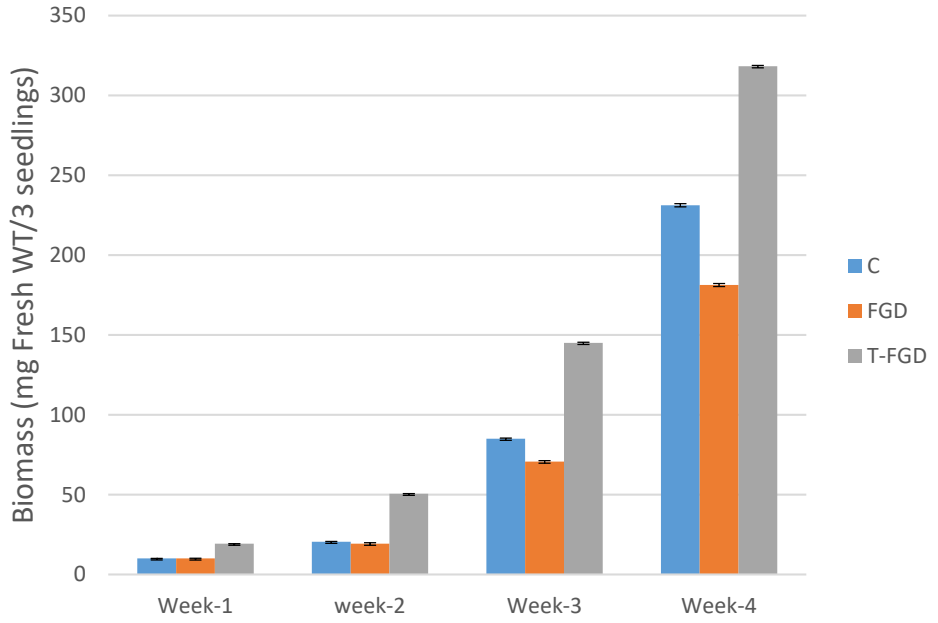




Growth of Algae in culture medium supplemented with FGD and T-FGD wastewater for week-1 to 3; B. Algae biomass measurement for week-1 to 3, data were derived from three replications. Data indicate that algal biomass growth rate was higher in medium supplemented with FGD and T-FGD wastewater. C: Control;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

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



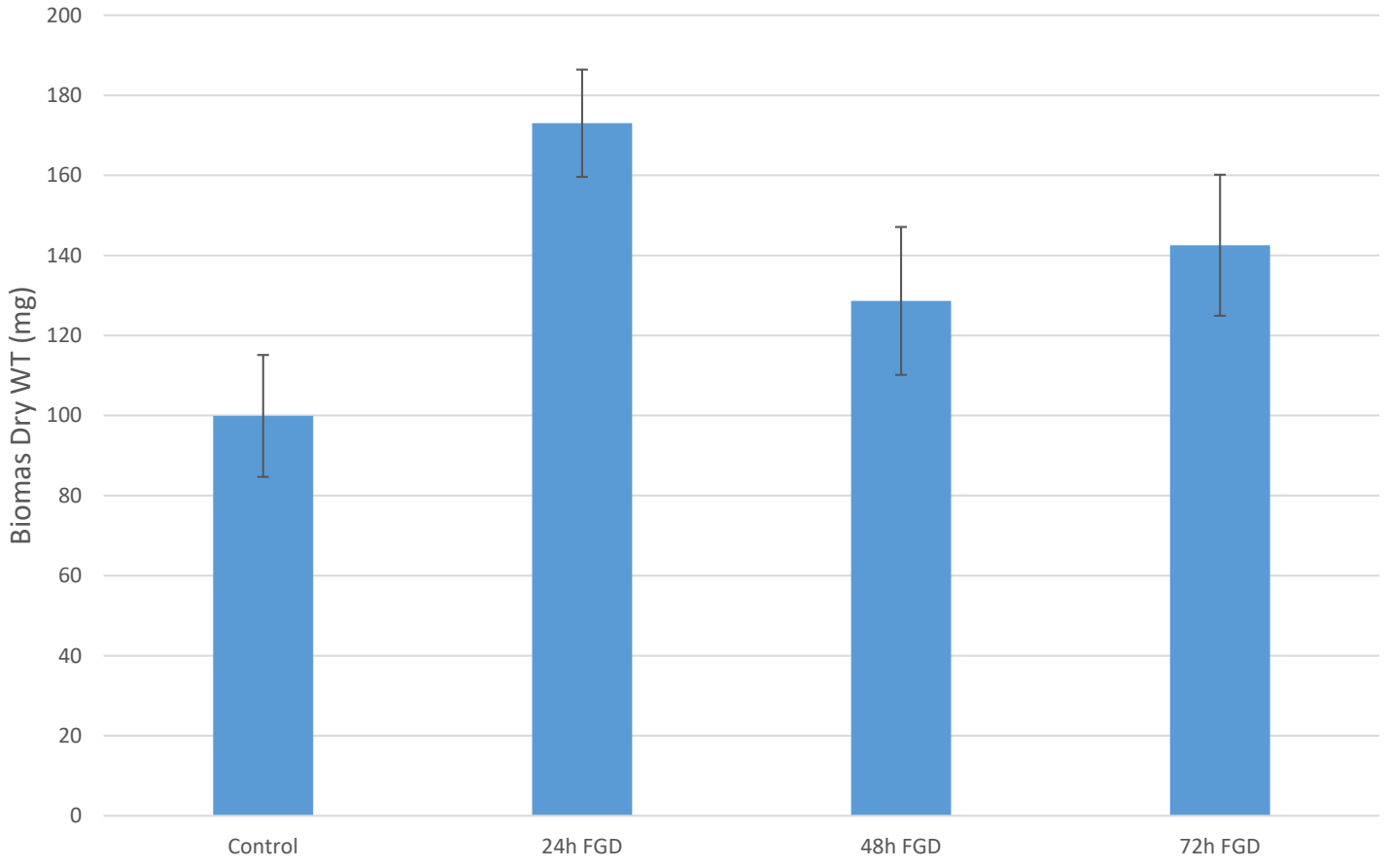


A. Growth of Arabidopsis in soil watered with FGD and T-FGD wastewater for week-1 to 3; B. Plant biomass measurement for week-1 to 3, data were derived from three replications. Data indicate that plant biomass growth rate was higher in plants watered with T-FGD wastewater. C: Control; FGD: Flue gas desulfurization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

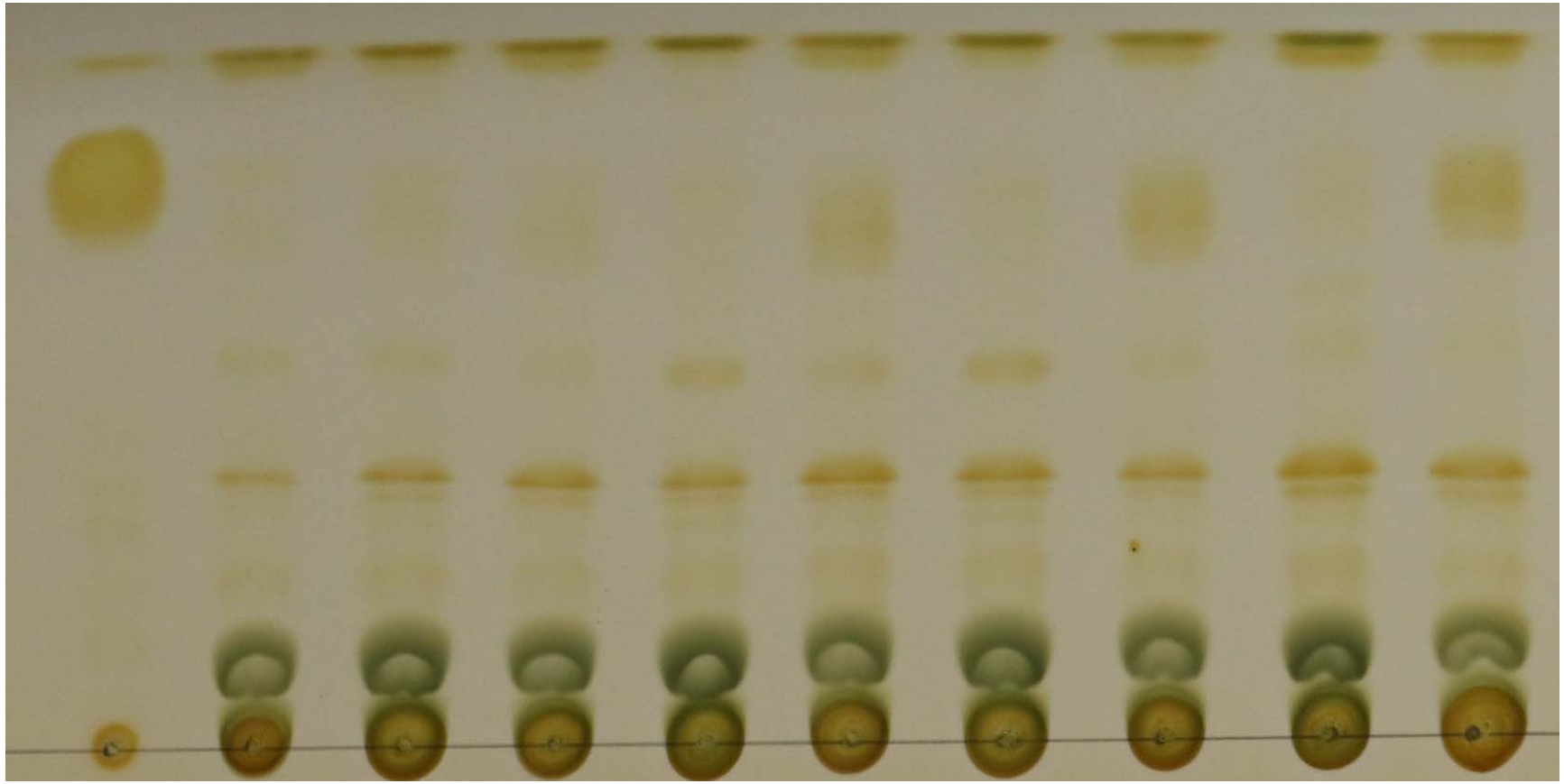
Effect of FGD wastewater on Duckweed biomass

Control FGD T-FGD

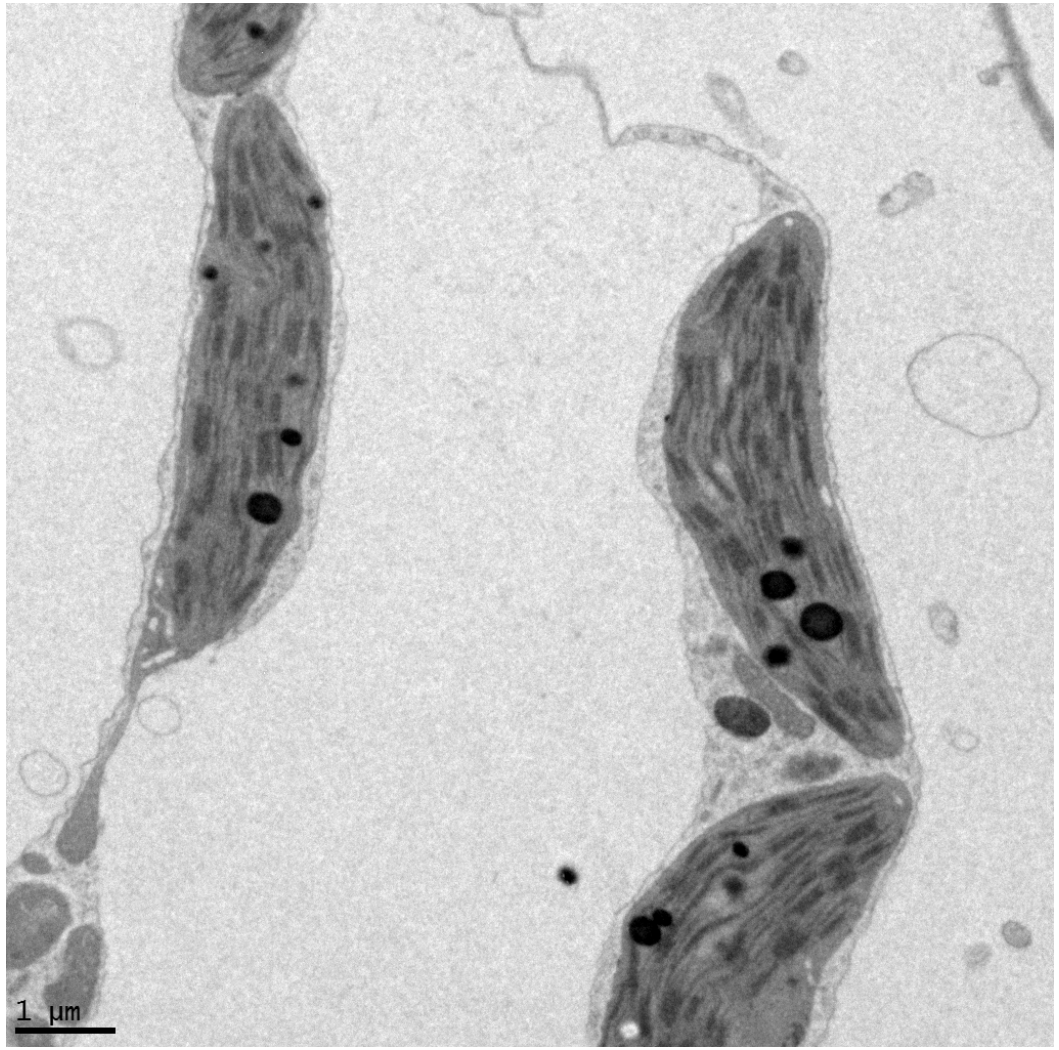
Treatment of Duckweed with FGD wastewater increases weight



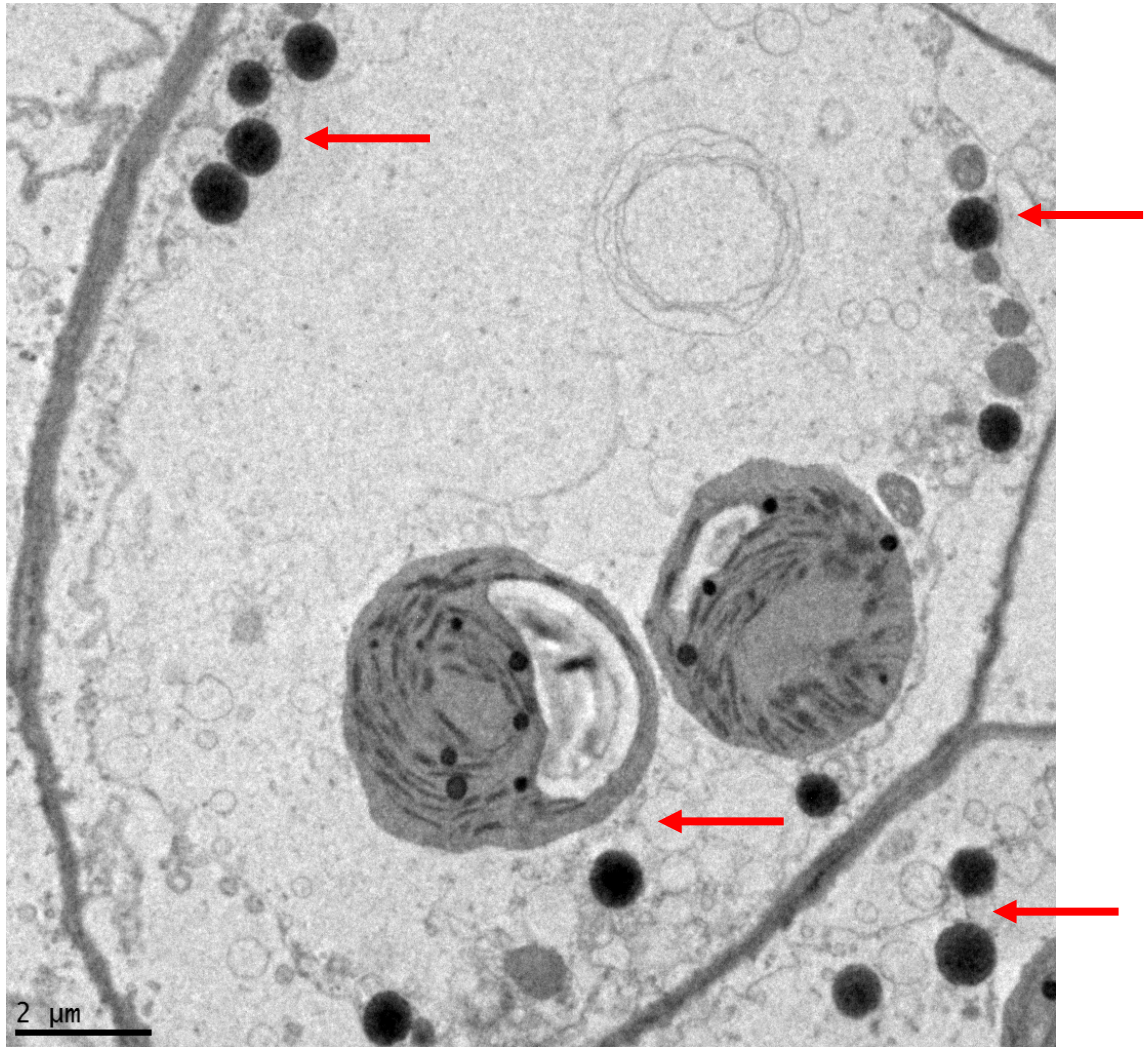
Effect of FGD Wastewater on Lipid Production in Duckweed



FGD wastewater treatment promote the accumulation of lipid droplets in Duckweed

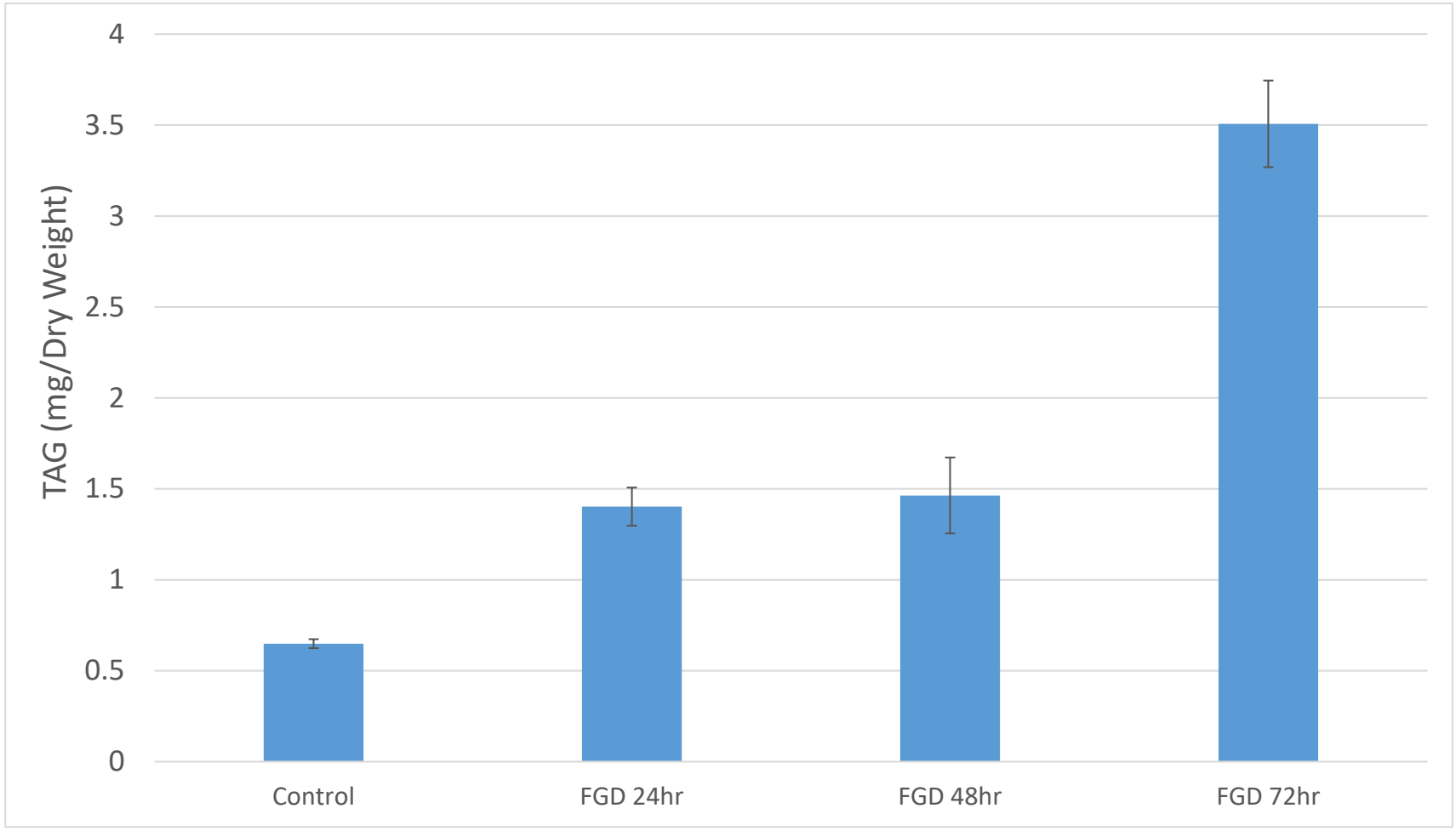


72hr control

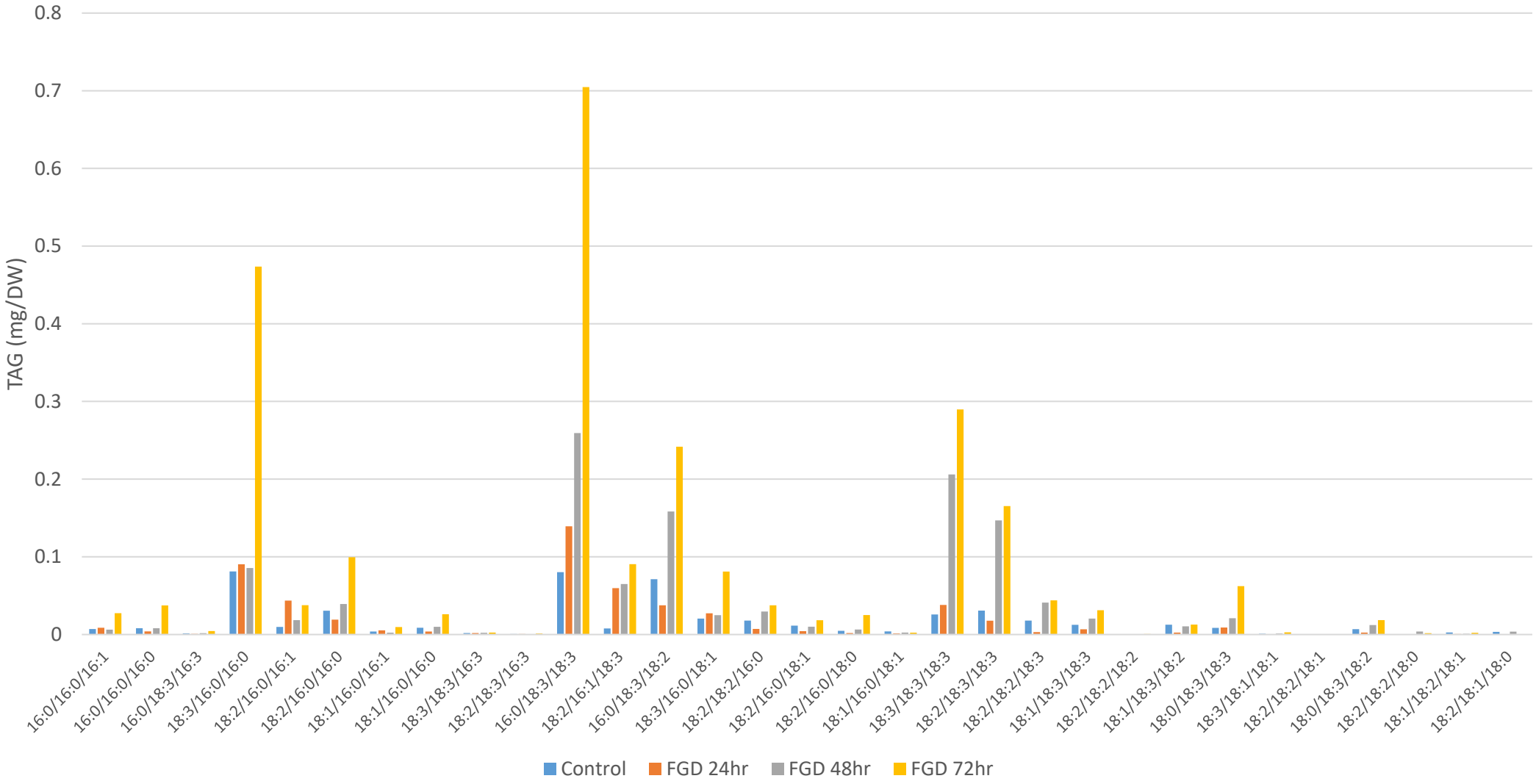


72hr FGD

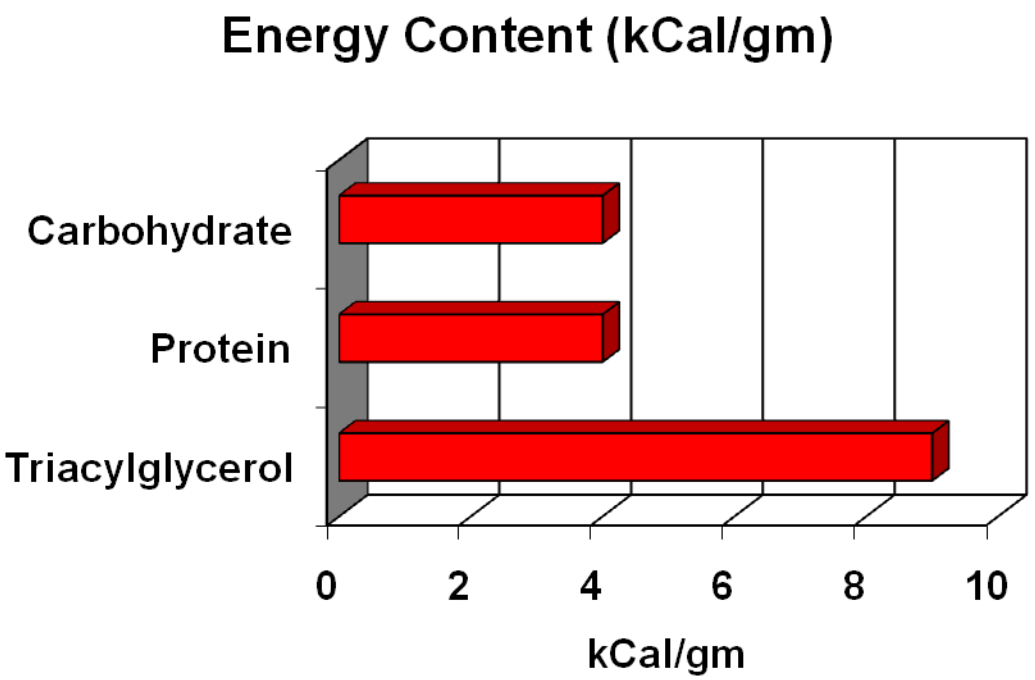
Quantification of Total TAG content in Duckweed using GC/MS



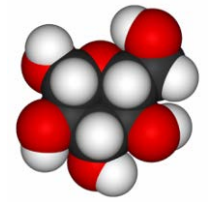
Analysis of Different Lipid Species Using GC/MS



TAG/Oils Are the Most Energy-Dense Plant Products

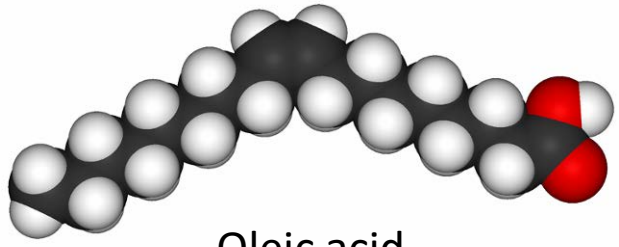


Oils have twice the energy content of carbohydrate and proteins



Glucose
(CHOH)n

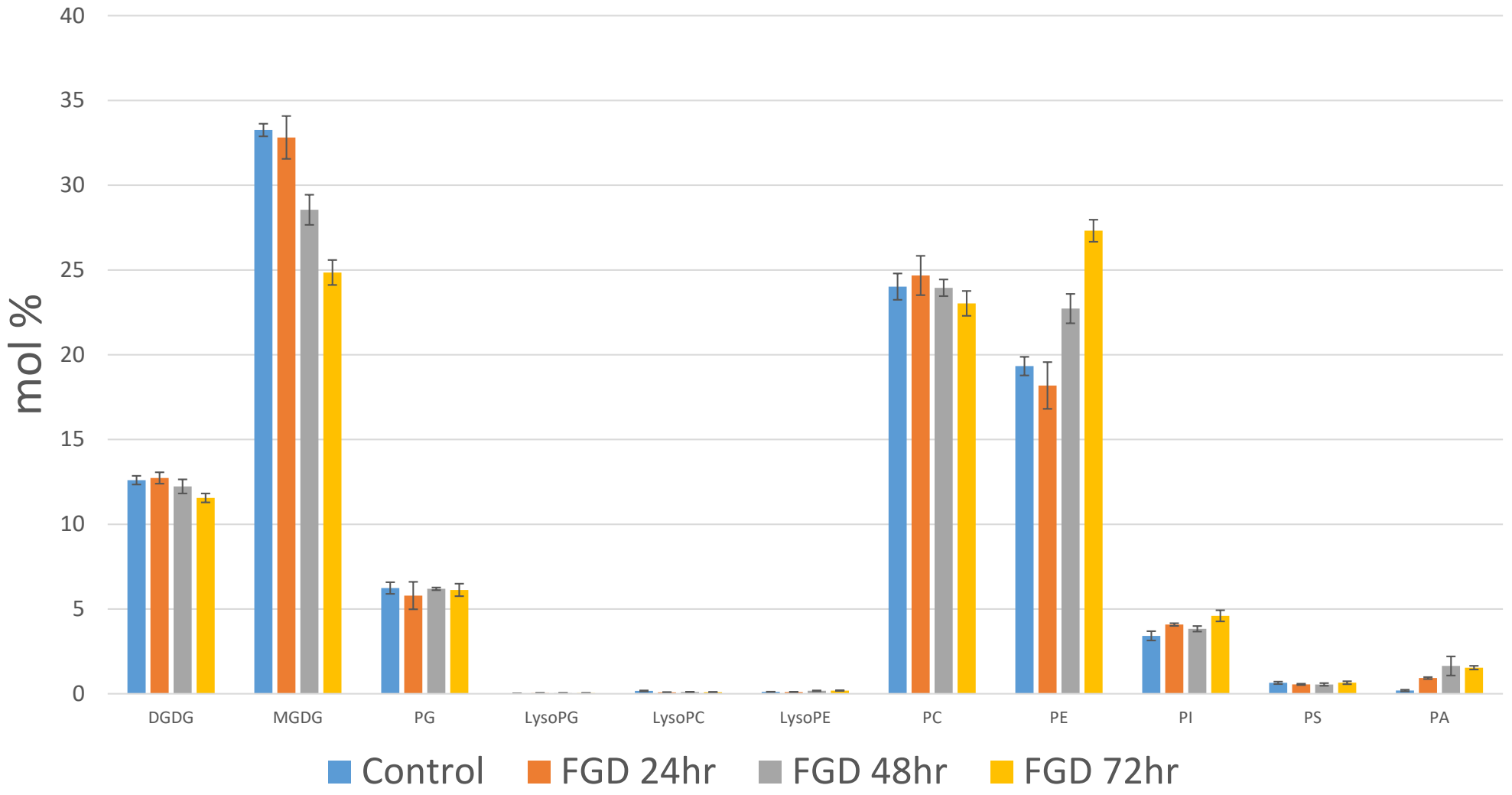
More Reduced Carbon



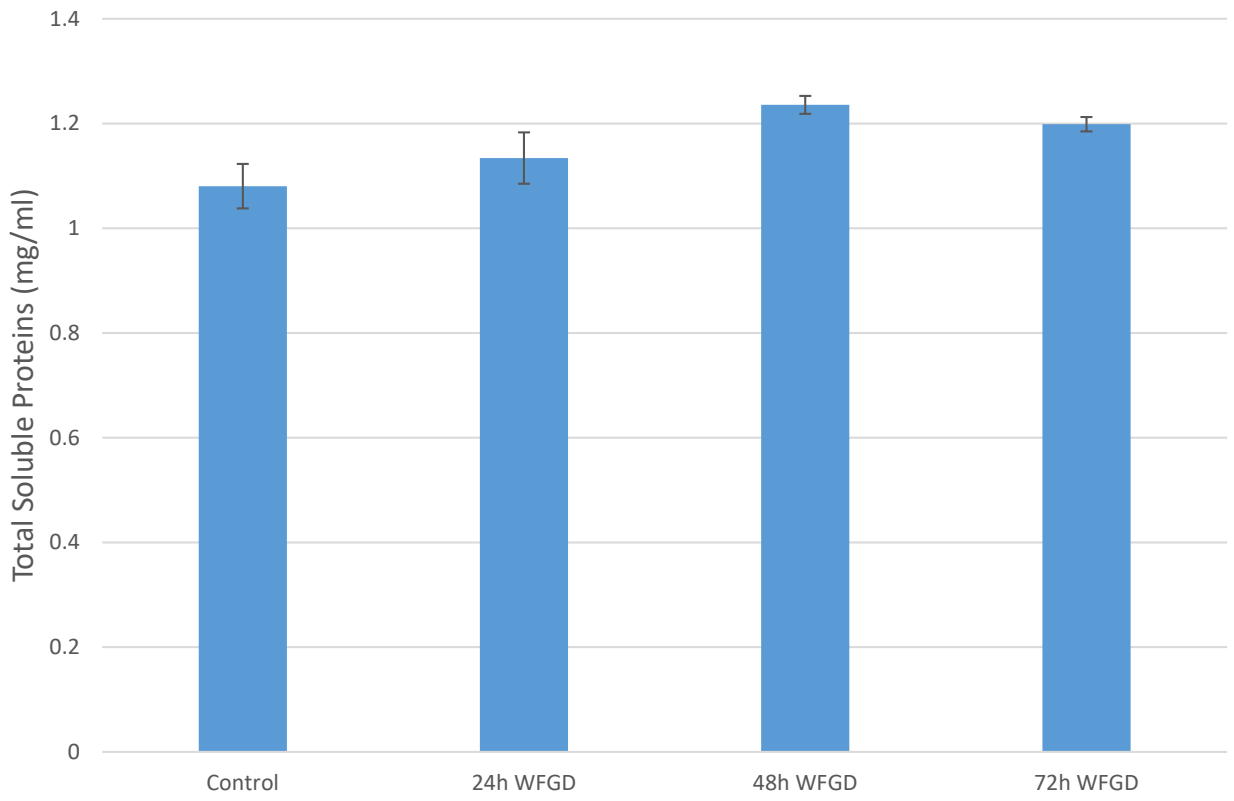
Oleic acid
$CH_3(CH_2)nCOOH$

Ohlrogge and Chapman, 2011, The Biochemical Society, April, 34-38

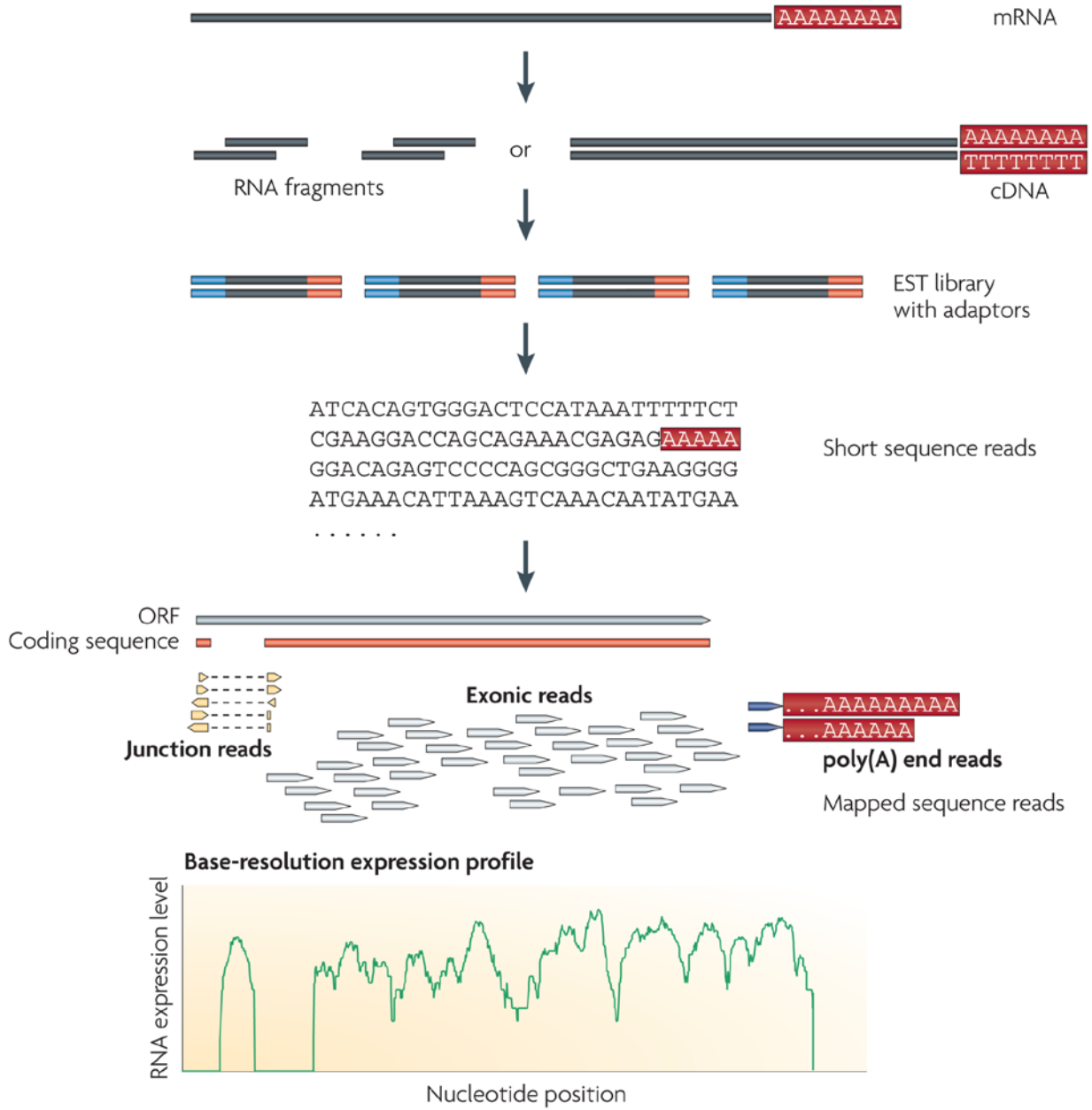
Analysis of Lipid Composition in Duckweed



Change in the Total Protein Content

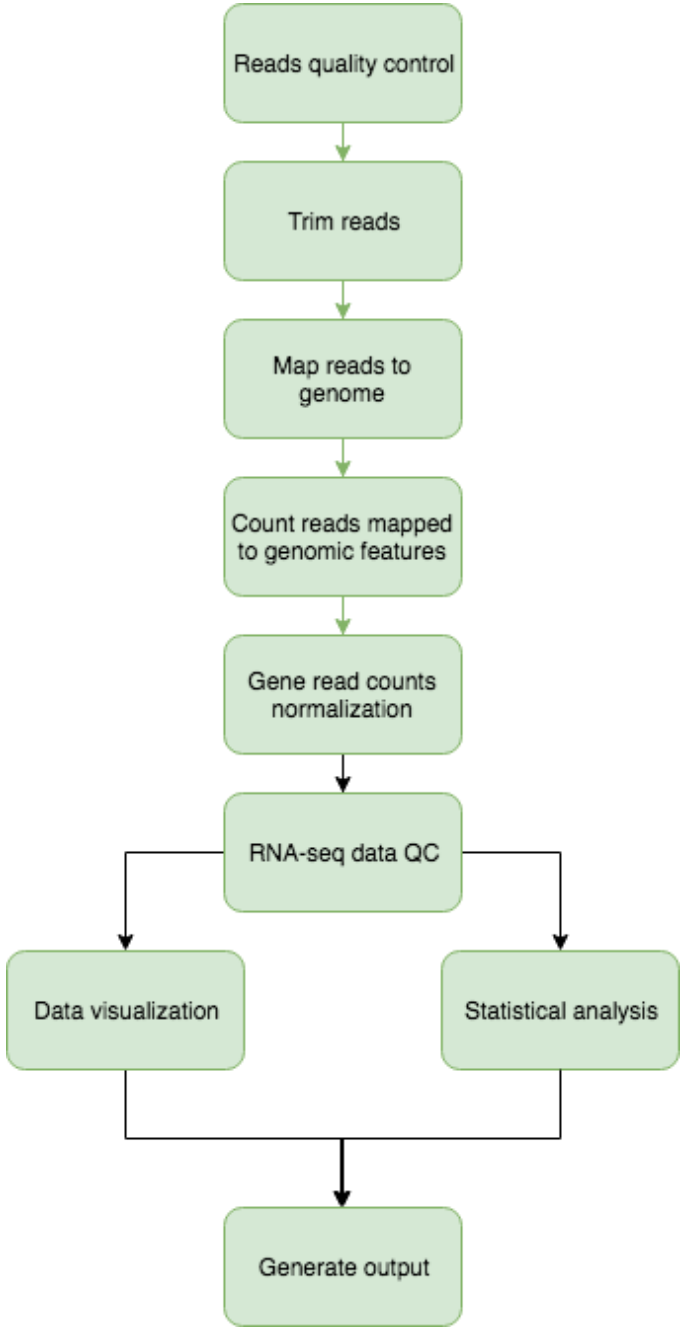


Perform post-sequence analysis and qRT-PCR analysis



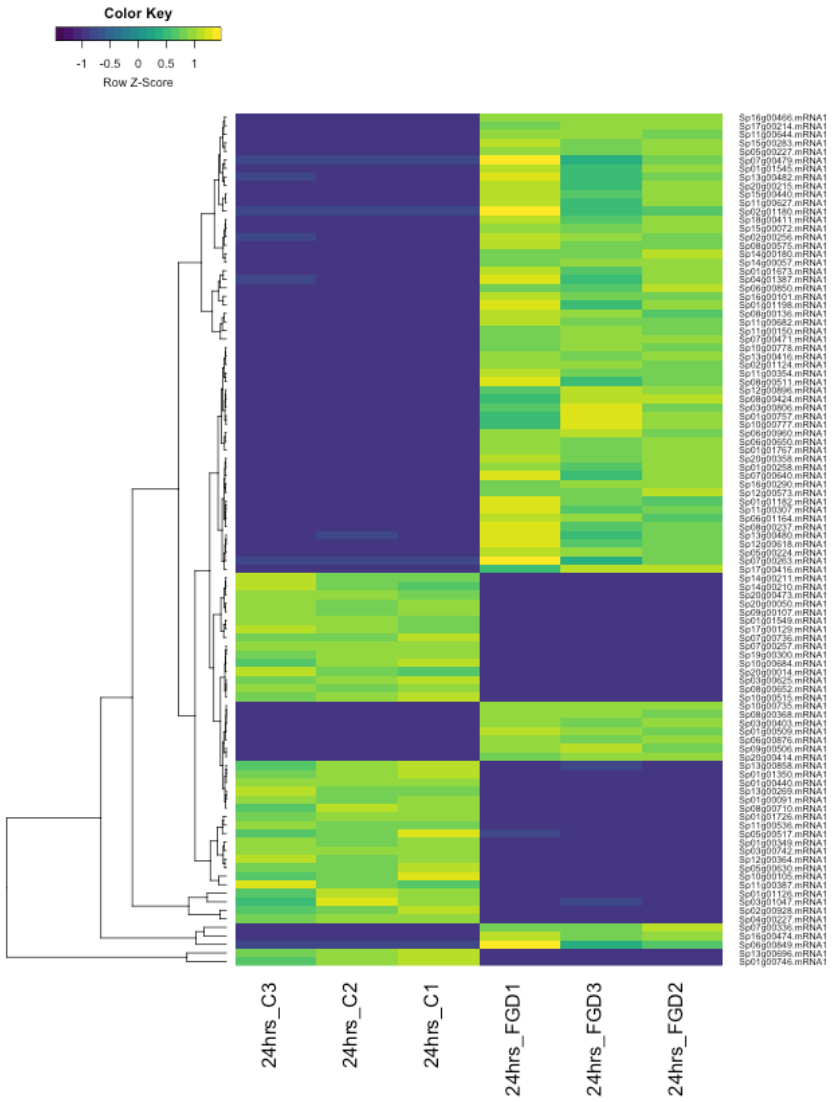
Wang et al., 2009. *Nat Rev Genet*; 10(1): 57–63

RNA-Seq Workflow

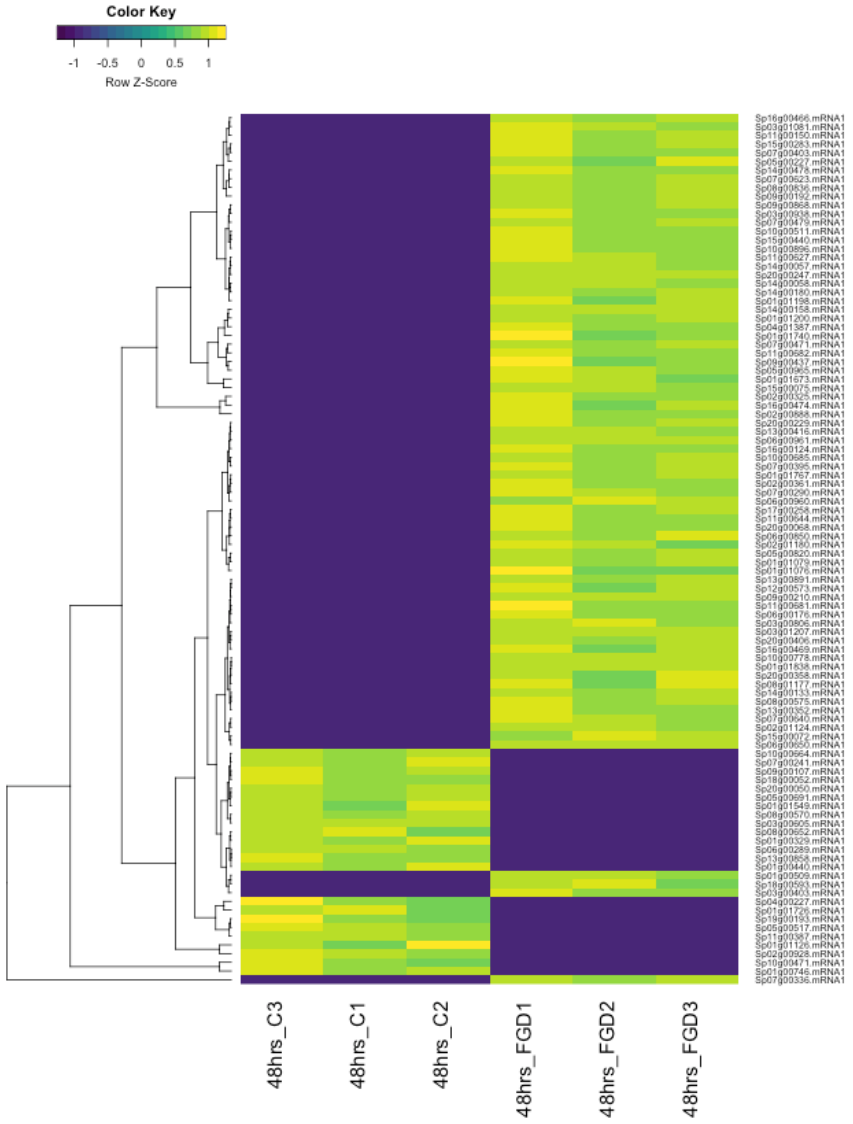


Heat map of top differentially expressed genes in Duckweed

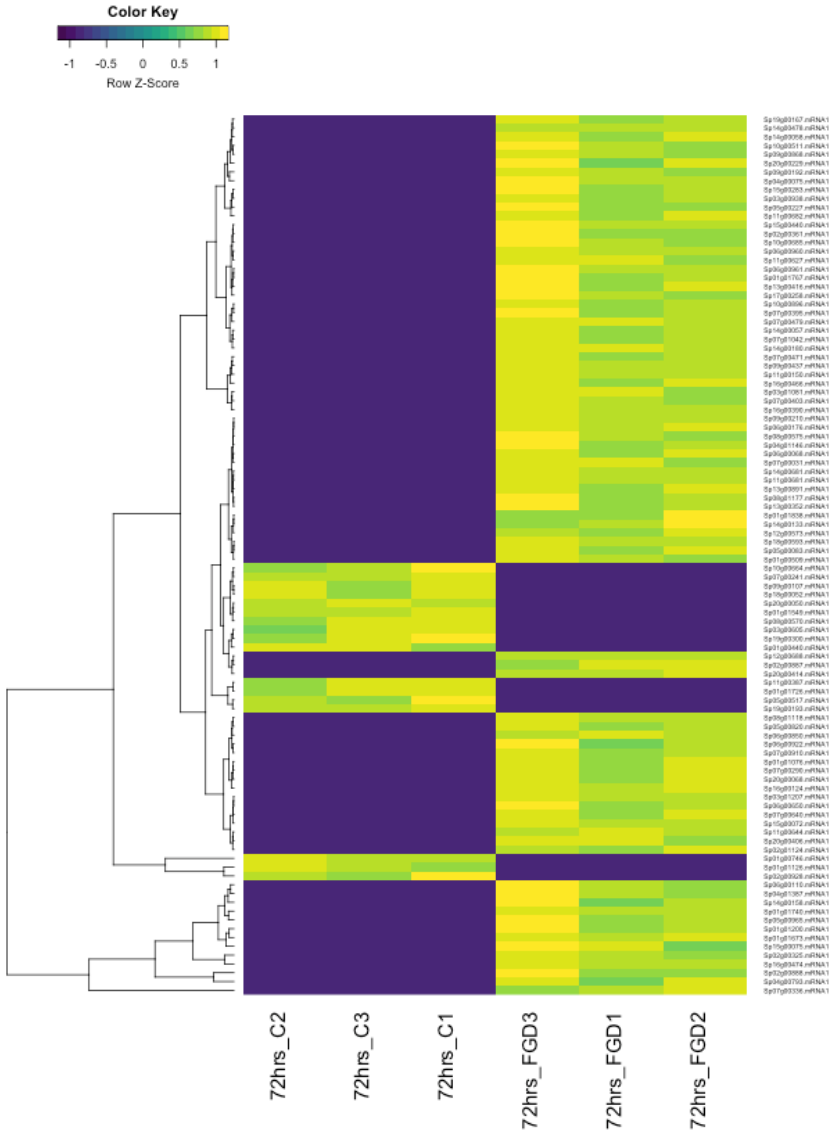
Contrast between C24 VS FGD24



Contrast between C48 VS FGD48

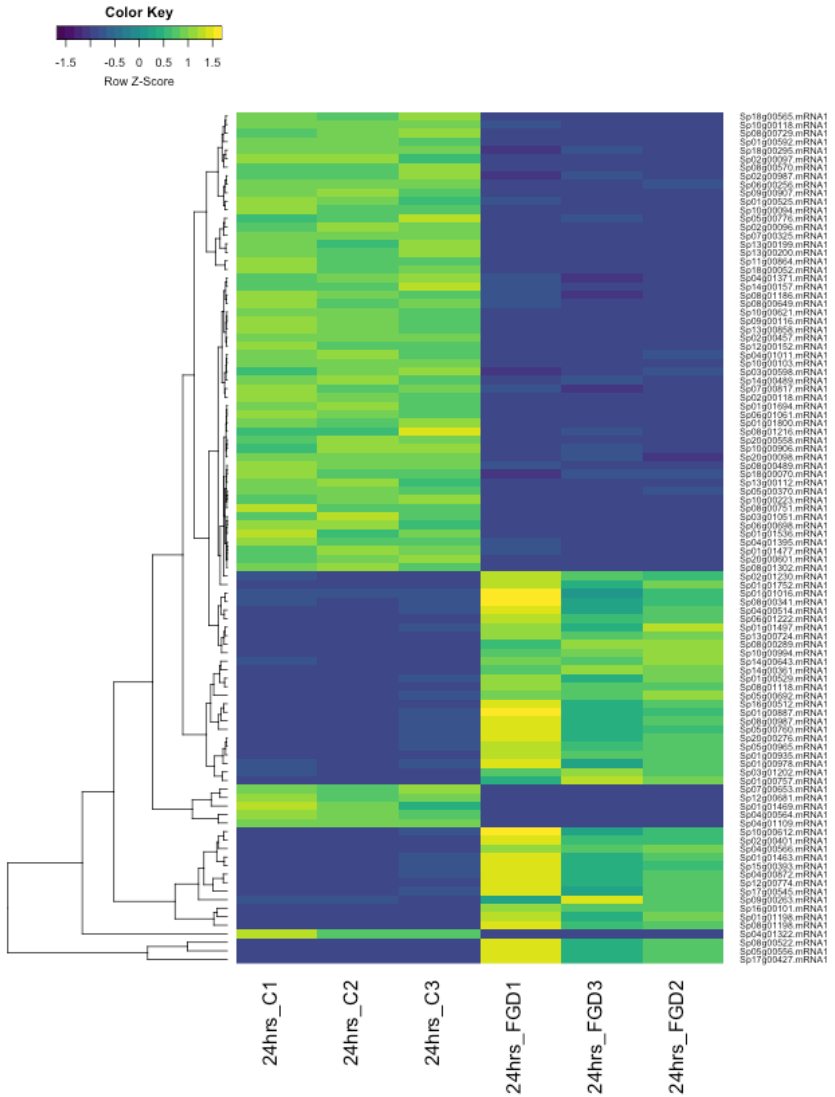


Contrast between C72 VS FGD72

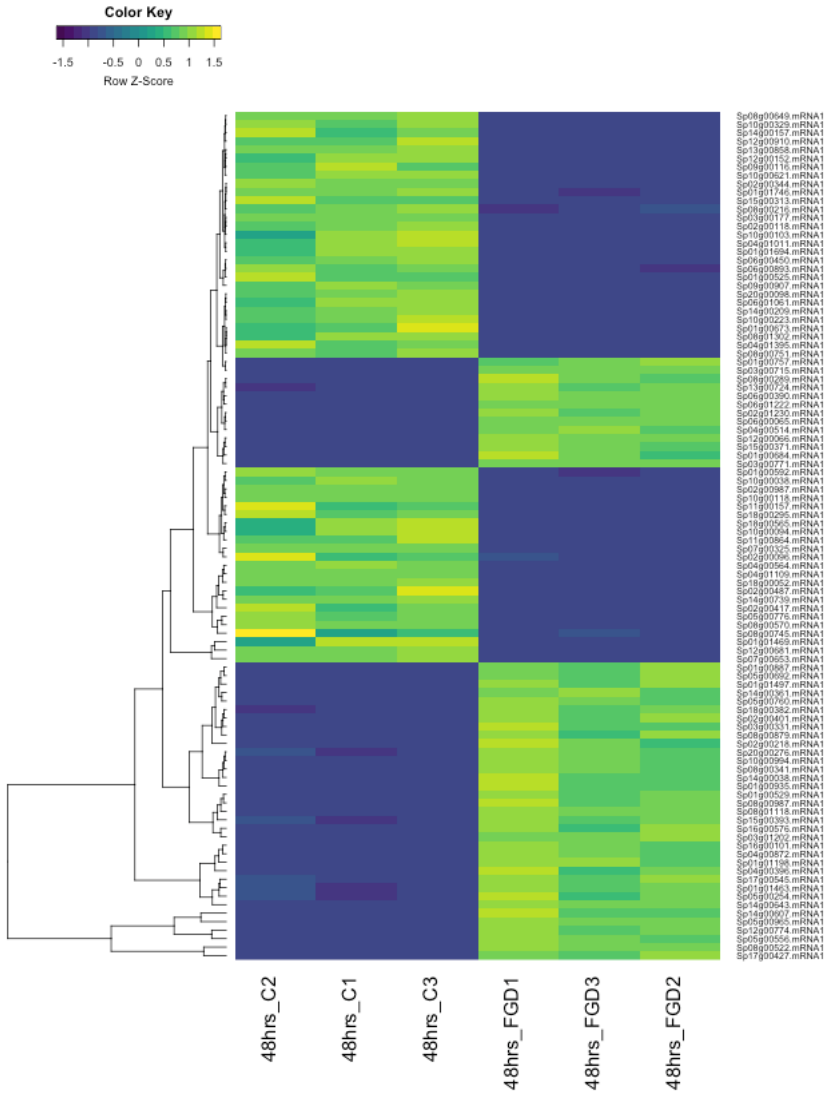


Differentially expressed Lipid related genes heat maps in Duckweed

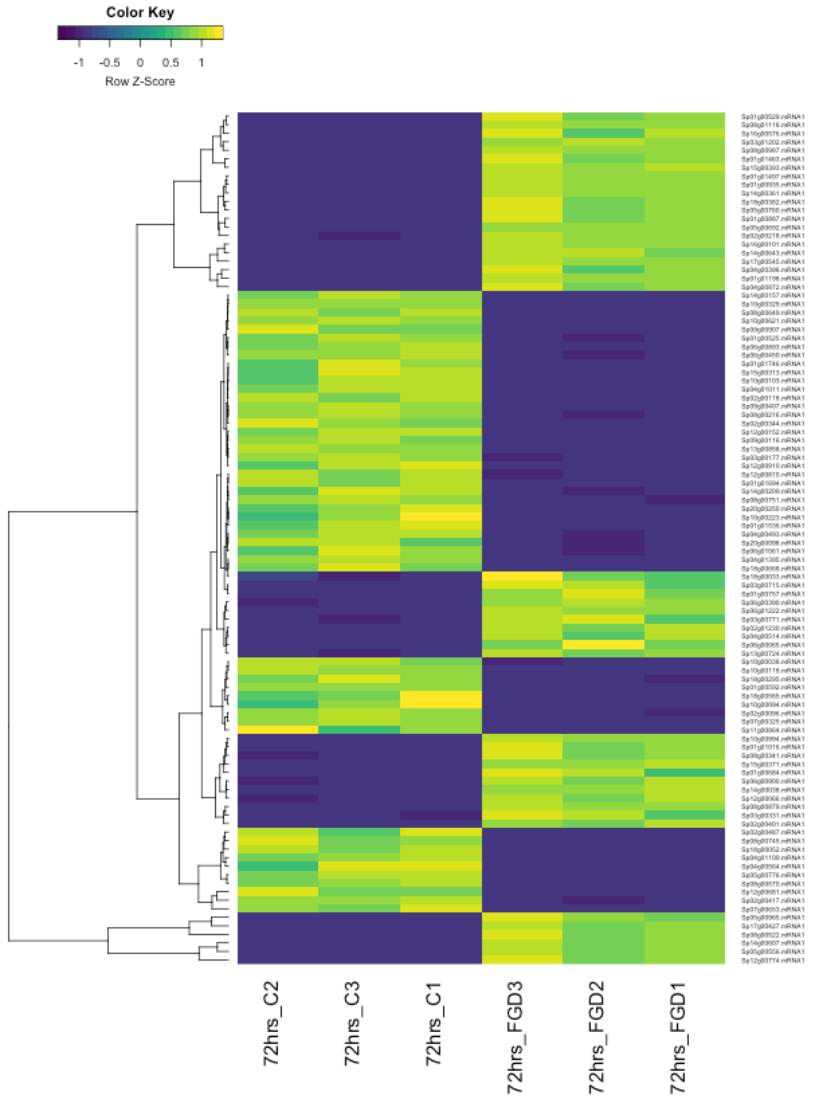
Contrast between C24 VS FGD24



Contrast between C48 VS FGD48

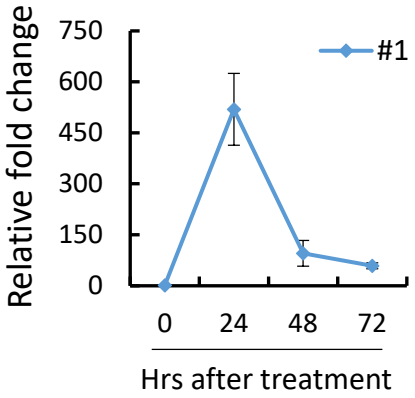


Contrast between C72 VS FGD72

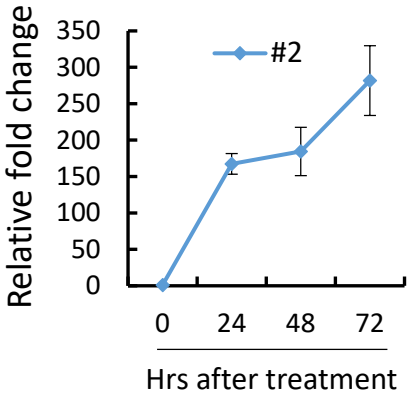


RT-qPCR analysis of Fatty acid biosynthesis genes in Duckweed

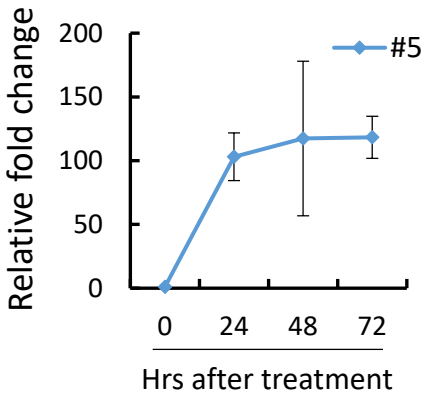
TAG Lipase



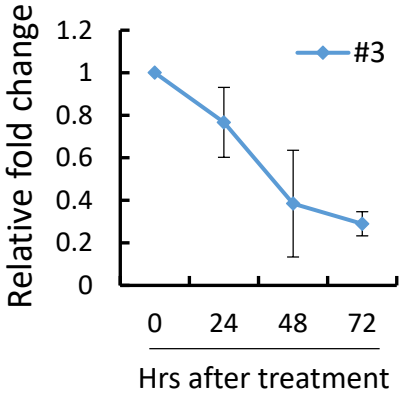
Aminophospholipid ATPase



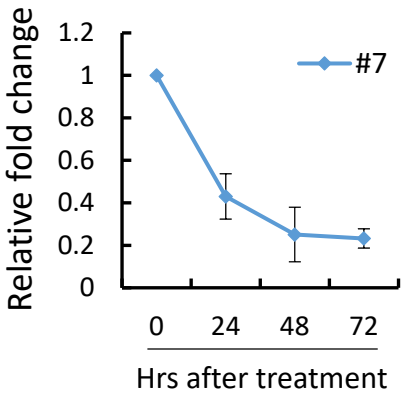
Long-Chain Acyl-CoA Synthetase



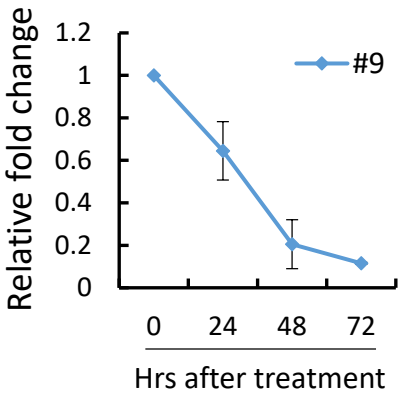
Oleate Desaturase



Oxo-Phytodienoic Acid Reductase



Golden2-like

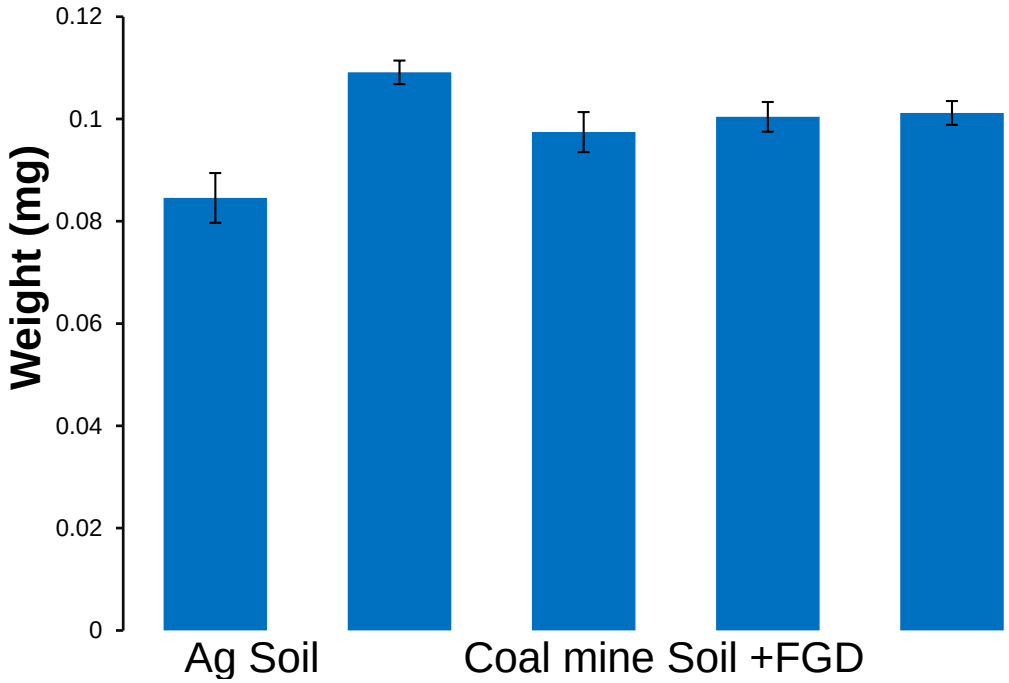


Perform functional analysis of candidate genes in model system

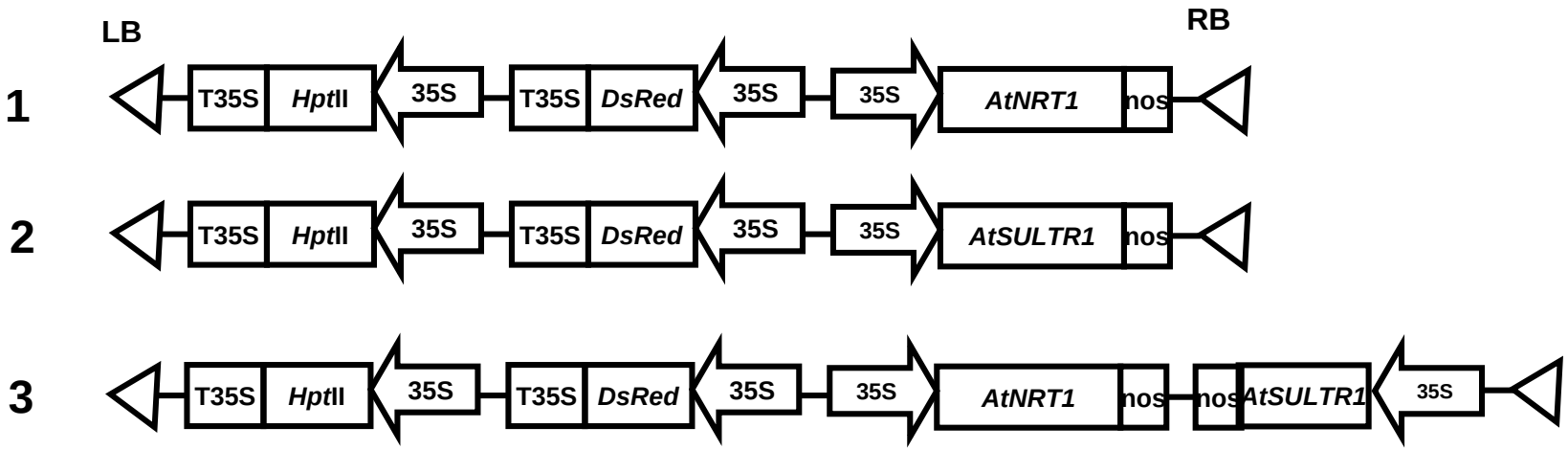
- Short generation time-6-8 weeks from seed-seed
- Small size
- Wider adaptability
- Self-fertilization
- Susceptibility to Agrobacterium infection
- Small genome size -125 million base pairs
- Large collection of T-DNA

Effect of FDG wastewater on coal mine soil and establishment of energy crop

Coal mine soil supplemented with FGD wastewater increase seed yield



Schematic representation of binary vectors used for transgenic plants establishment



Current status:

Homozygous lines are established…

Learning Water Quality in a Class Room

Oral and Poster presentation in 1890 ARD symposium, Jacksonville, FL 2019
Oral presentation in ASPB Midwest section, WVU symposium, 2019
Oral presentation in Gordon Research Conference on Plant lipids, Galveston, TX, 2019

Studying the Effect of Soil on Plant Physiology

Preparing Project for Next Steps

- FGD wastewater treatment triggered the accumulation of useful fatty acids in the Duckweed, the potential of this technology need to be investigated.

- Supplementation of FGD wastewater in coal mine soil promoted the growth of energy crops, use of FGD wastewater in re-use in Agriculture needs to be determined.

Concluding Remarks

- Completed the RNA Seq experiments for duckweeds treated with FGD wastewater for different time course and identified candidate genes involved in fatty acids and metal sequestration.

- Demonstrated the re-use of FGD wastewater in Agriculture on coal mine soils using bioenergy crop.

Acknowledgement

Josh Davidson; Bagya Muthan; Joseph Baird; Tawna Heath; Thanh Nauyen and Krishna Challa, Bhikash Deo, Subhiksha Khathiwada, and Justin Bradley

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Bio-Chem Testing, Inc.,

MICHIGAN STATE UNIVERSITY