Evaluation of a Biochar Enhanced Constructed Treatment Wetland for the Removal of Contaminants from Agricultural Wastewater

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Agricultural Wastewater

- Concentrated animal feeding operations (CAFO)
- Contaminants of Concern – nitrogen, phosphorous, heavy metals, antibiotics, hormones, pathogens
- CAFO wastewater management and impacts on environment
- Environmental and human health effects



Need: low-cost, low-maintenance treatment technologies

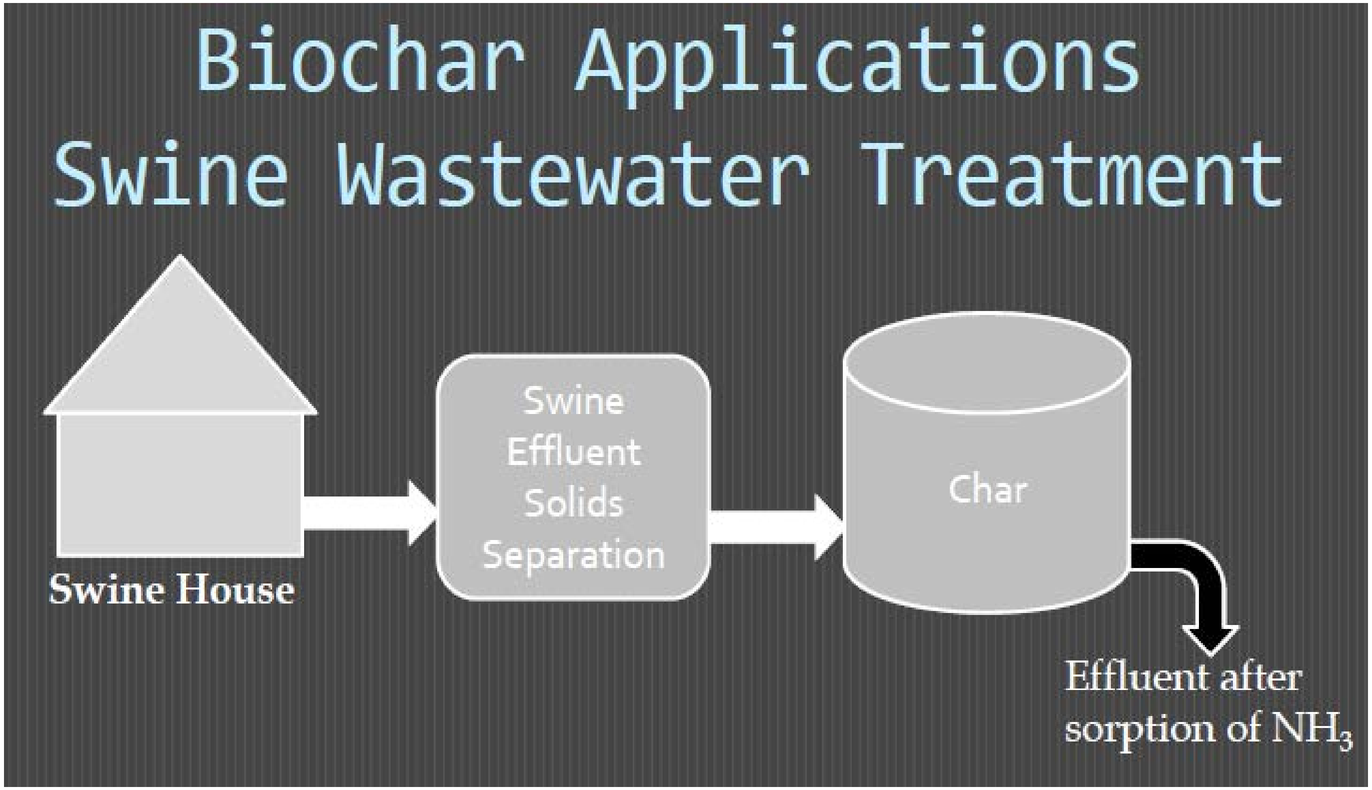
Goal of this study

- Evaluate performance of biochar reinforced wetlands for filtration and treatment of CAFO wastewater.

- Hypothesis: The treatment effectiveness of a constructed treatment wetland system can be significantly improved by combining the functions of biochar and plants.

Prior Work

NCSU, USDA/ARS and Stonybrook Univ.



Reddy et al., 2012

Biochar and phytoremediation treatment system

- Biochar adsorbs nutrients, metals, organics (physical removal), and increase plant growth and microbial activity

- Plants take-up and utilize N, K, P (phytoremediation)

- Traditional constructed treatment wetlands (CTW) effective for nutrient removal, but require large land area

Biochar and phytoremediation treatment system

- Why CTWs designed with biochar and plants could potentially be more efficient for WW treatment
  - Combine physical, biochemical and uptake of nutrients, metals and organics
  - Require less treatment area
  - More rugged, not susceptible to sudden changes (wastewater & environment)
  - Can be semi-passively operated for many years
  - Can operate solely on solar energy
  - Carbon is sequestered

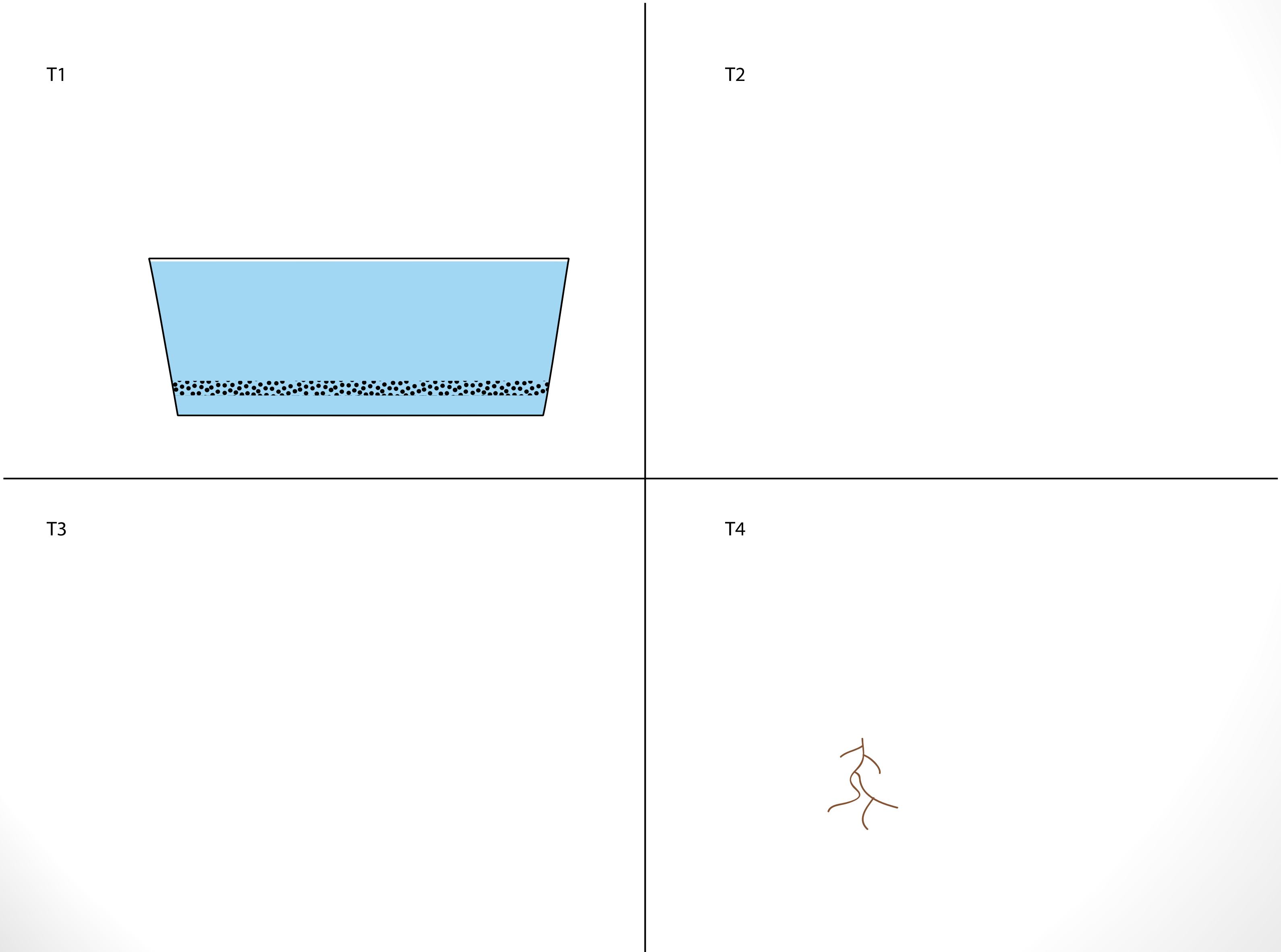
Biochar Properties

- Source of Biochar - Biochar Now
  - Soft wood biochar
  - Pyrolyzed at 550°C
  - 0.5mm – 2mm = 87%
  - > 2mm = 13%

Biochar sorption tests - Bench Scale Tests

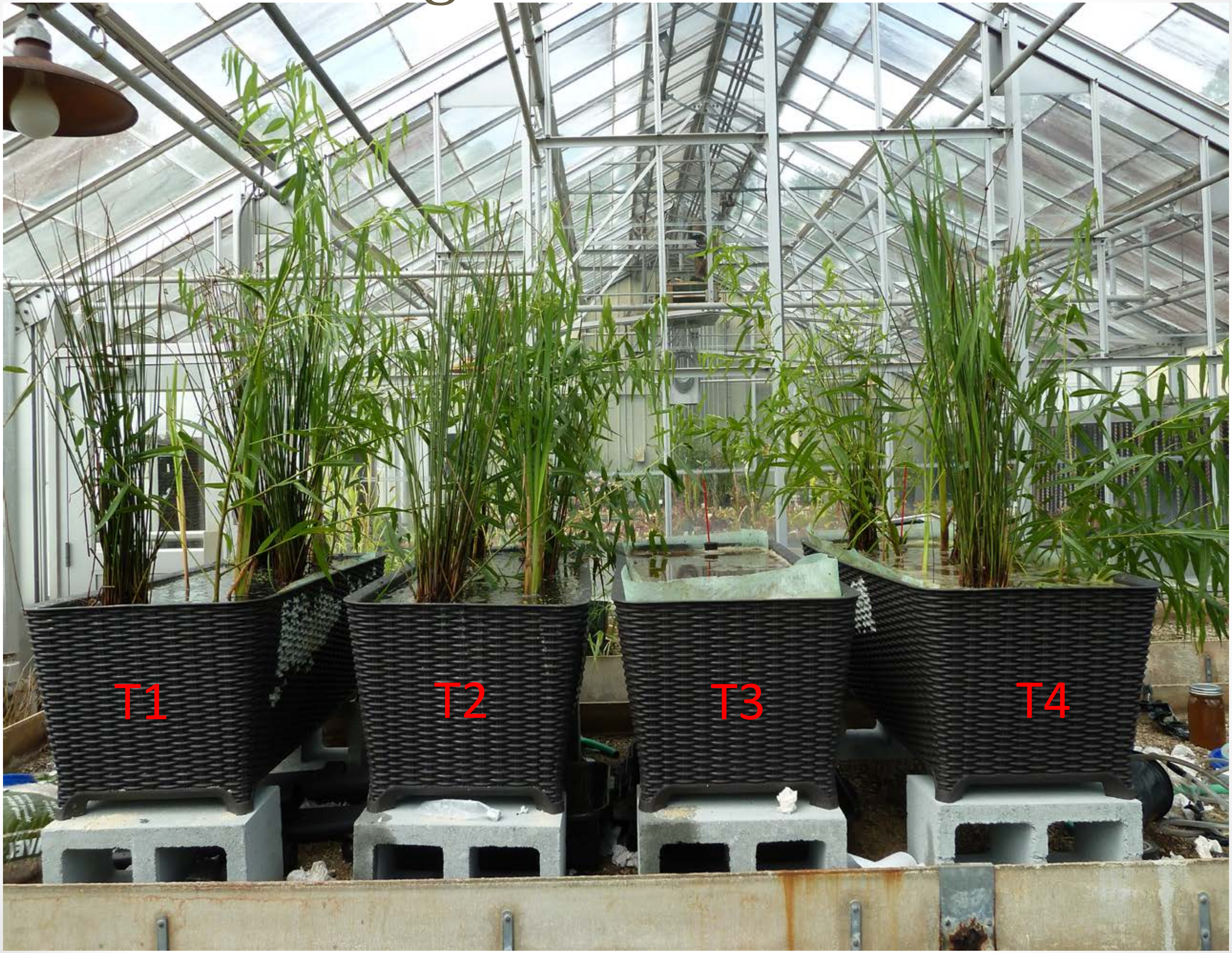
- NH_4^+ sorption reached equilibrium in <24 hrs
- NO sorption of NO_3^--N or PO_4^{3-}
- NH_4^+-N loading on biochar = 280 mg/Kg biochar
- 98% NH_4^+ desorbed from biochar into distilled water
  - Adsorbed NH_4^+ is bioavailable
  - Electrostatic forces primary sorption mechanism

Biochar + Plant Constructed Treatment Wetland Tests: Greenhouse experiment



Initial Planting

August, 2015



Initial Test – Fall 2015

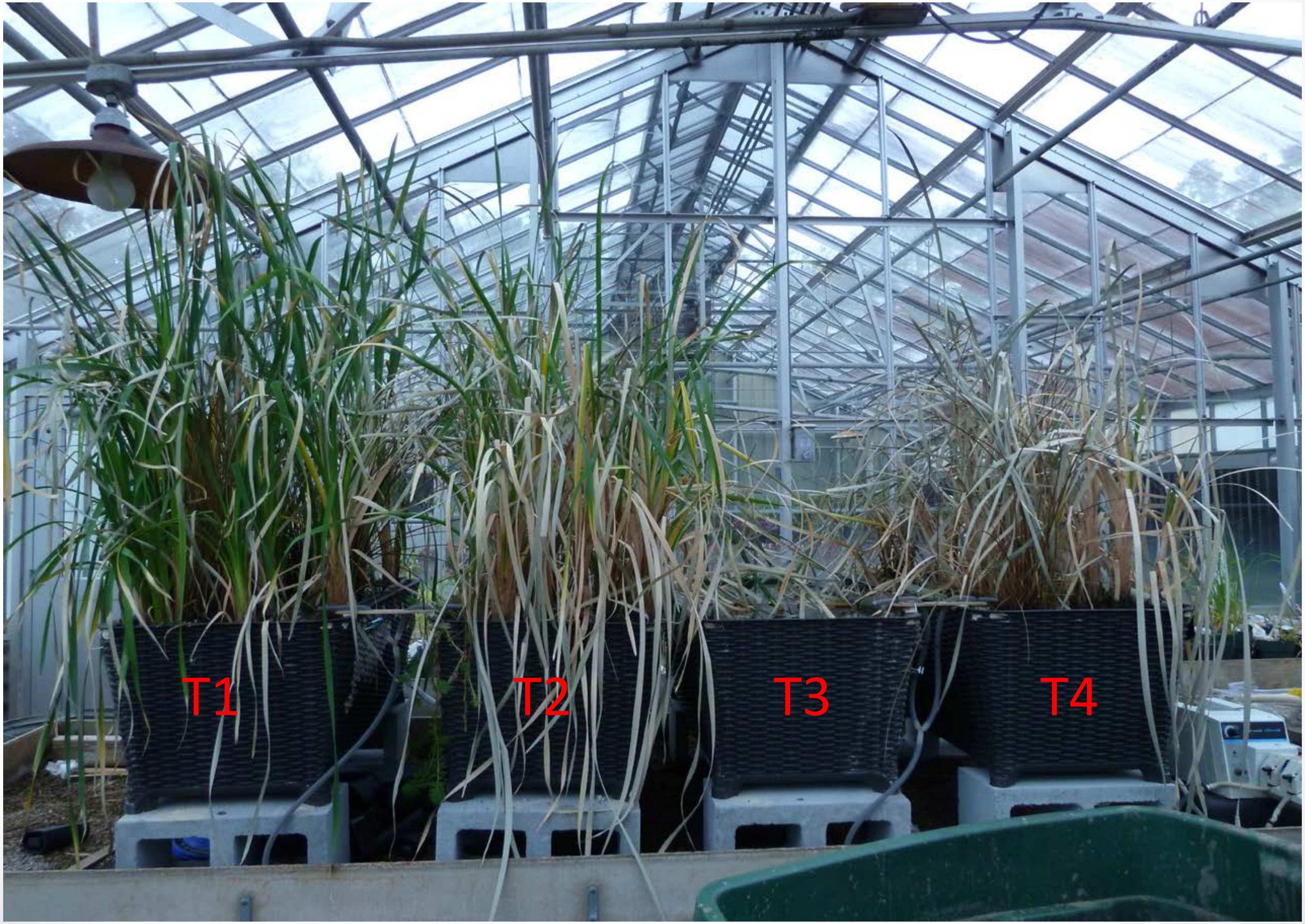
- Swine waste water – diluted x2
- Nutrient Initial Concentrations:

NH_3-N (mg/L)	636.2
NO_3^--N (mg/L)	9.45
PO_4^{3-} (mg/L)	94.4
pH	8.01

- Influent rate: 2L/hr
- Residence time in tanks: 33.5 hrs

End of Initial Fall Test

November, 2015



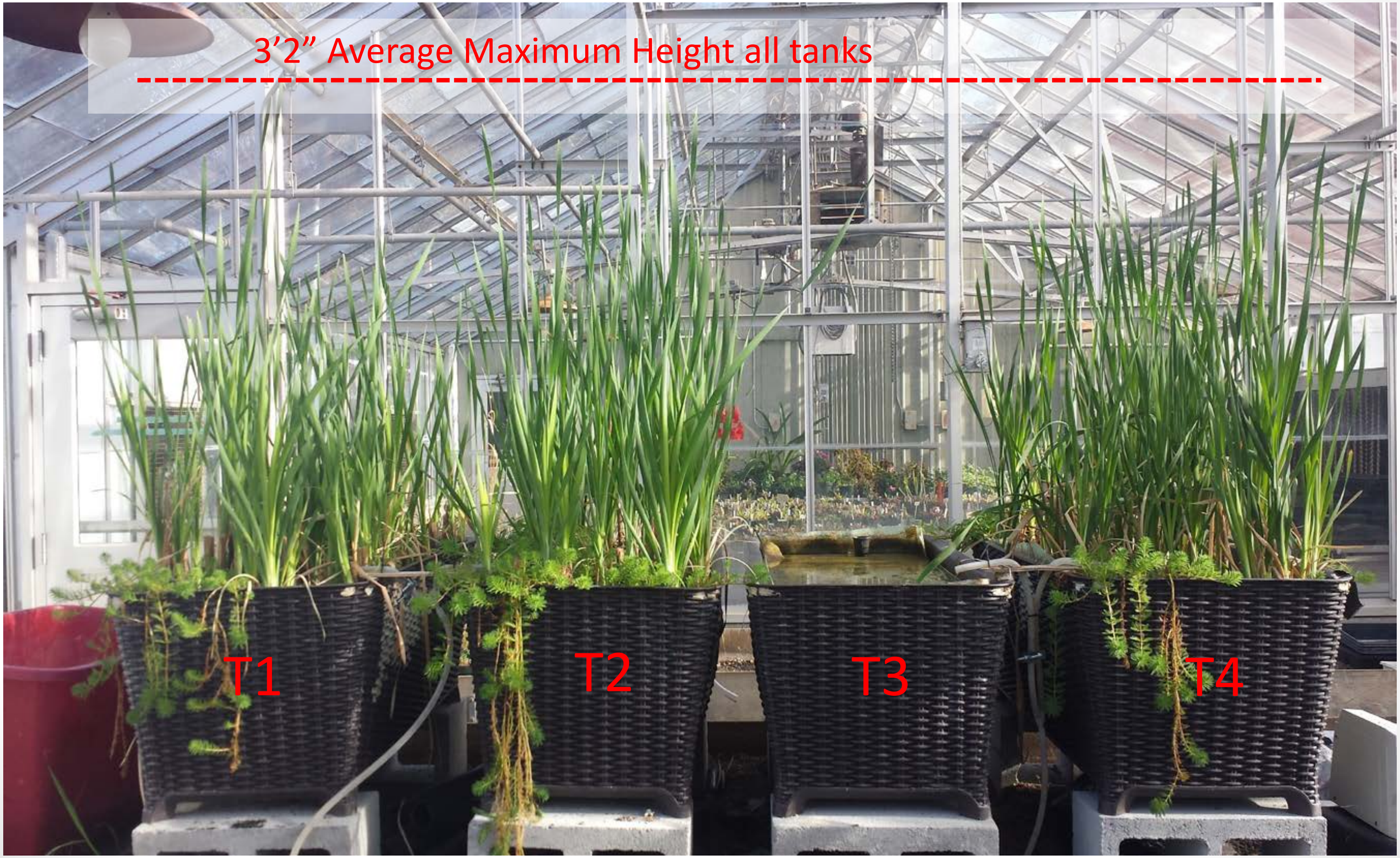
Second Test – Spring 2016

- April Test: swine waste diluted by 10X
- May-June: swine waste diluted by 5X
- Influent rate: 1L/hr; Residence time = 67 hrs

- Influent and effluent tested for: TS, COD, NH_4^+-N, NO_3^--N, TKN, PO_4^+, P, S, K, Na, Mg, Ca, Fe, B, Cu, Mn, Zn, Al

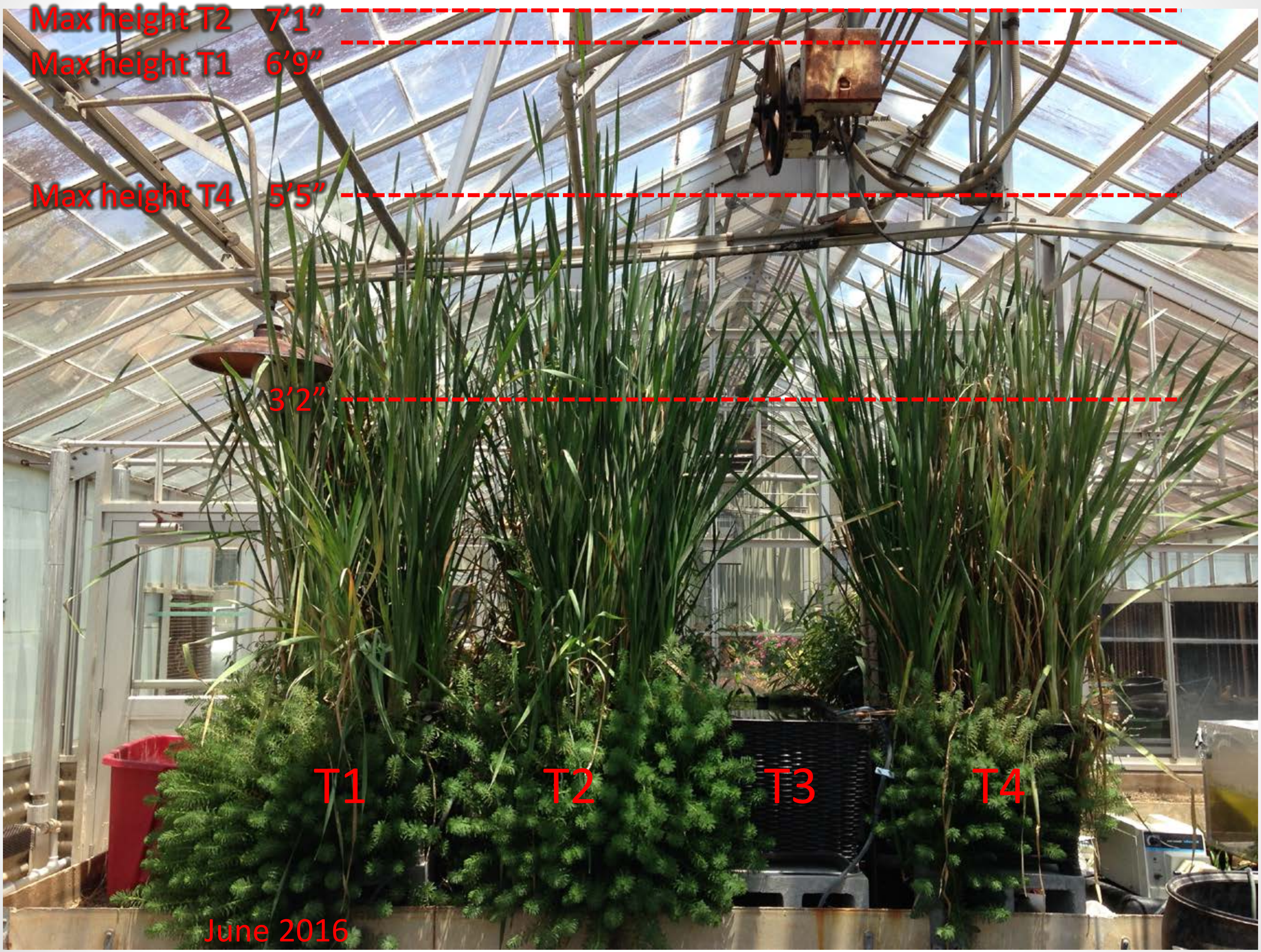
Second Test – Spring 2016

April 2016

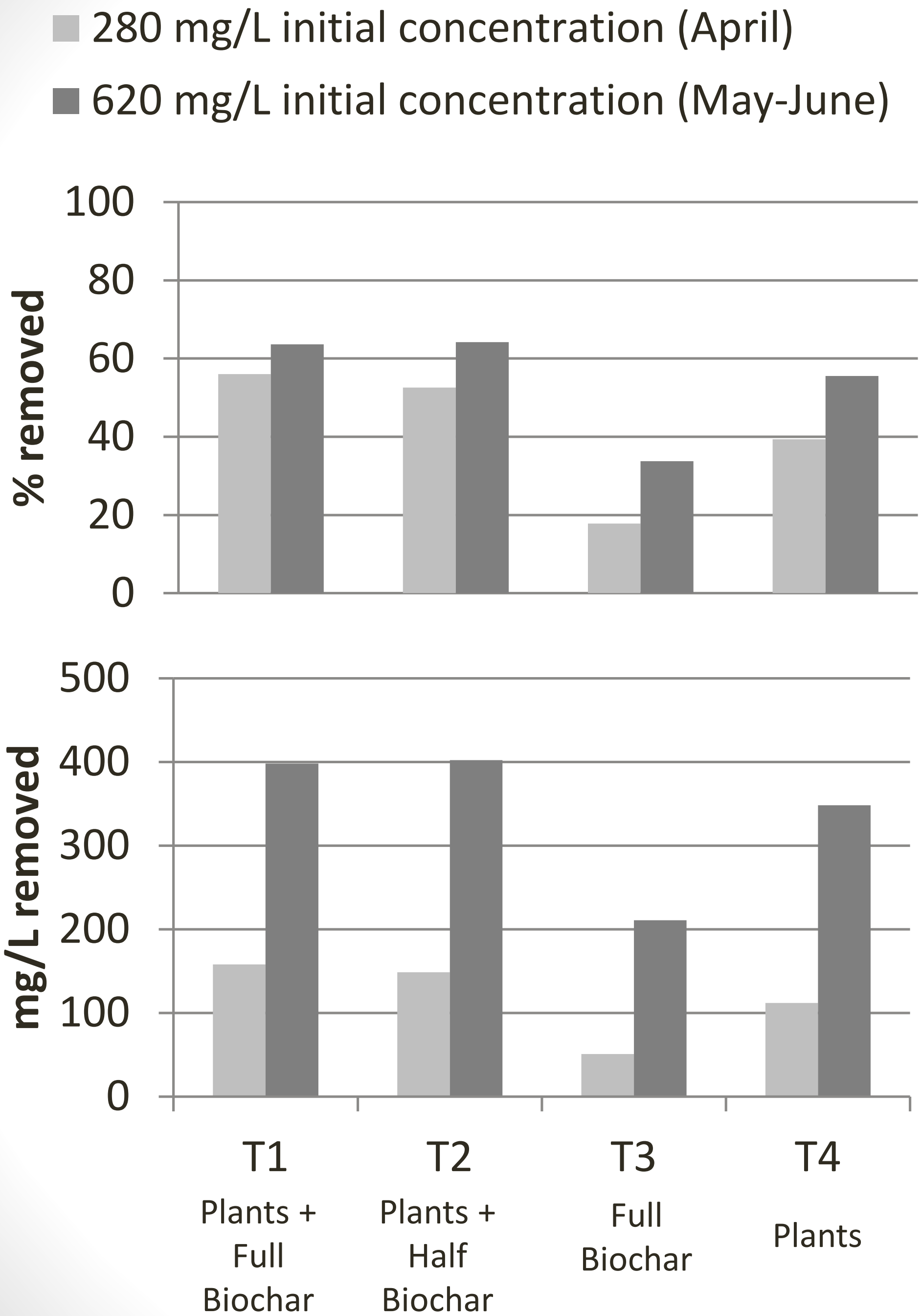


End of Second Test

June, 2016



Results – Total Solids Removal



Overall T1 removal

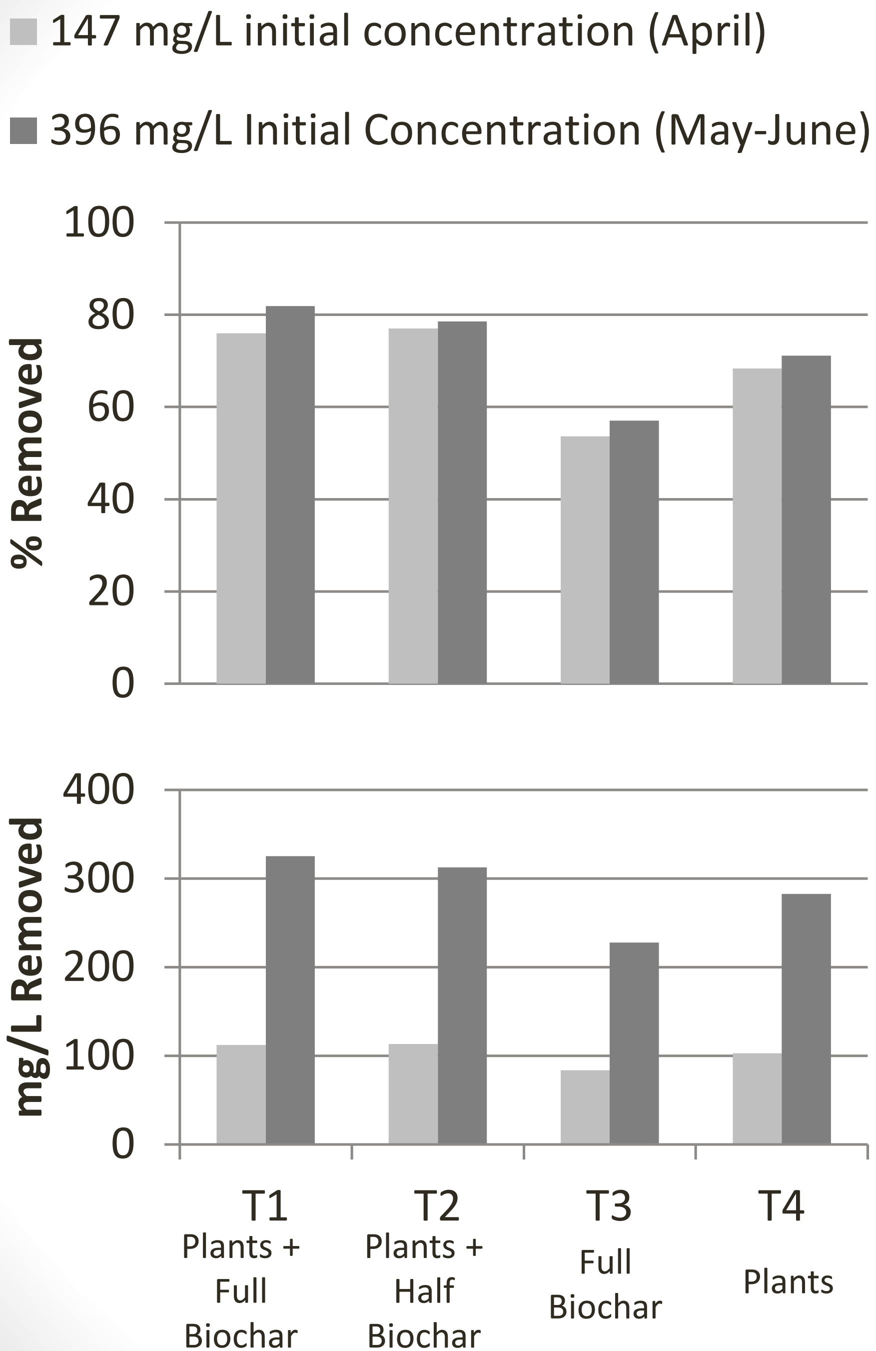
Equal to T2

51% more than T3

16% more than T4

- ✓ CTW with biochar plus plant (T1 and T2) performed best.
- ✓ Removal of Total Solids more than doubled in May-June for all tanks

Results – Chemical Oxygen Demand (COD) Removal



Overall T1 removal

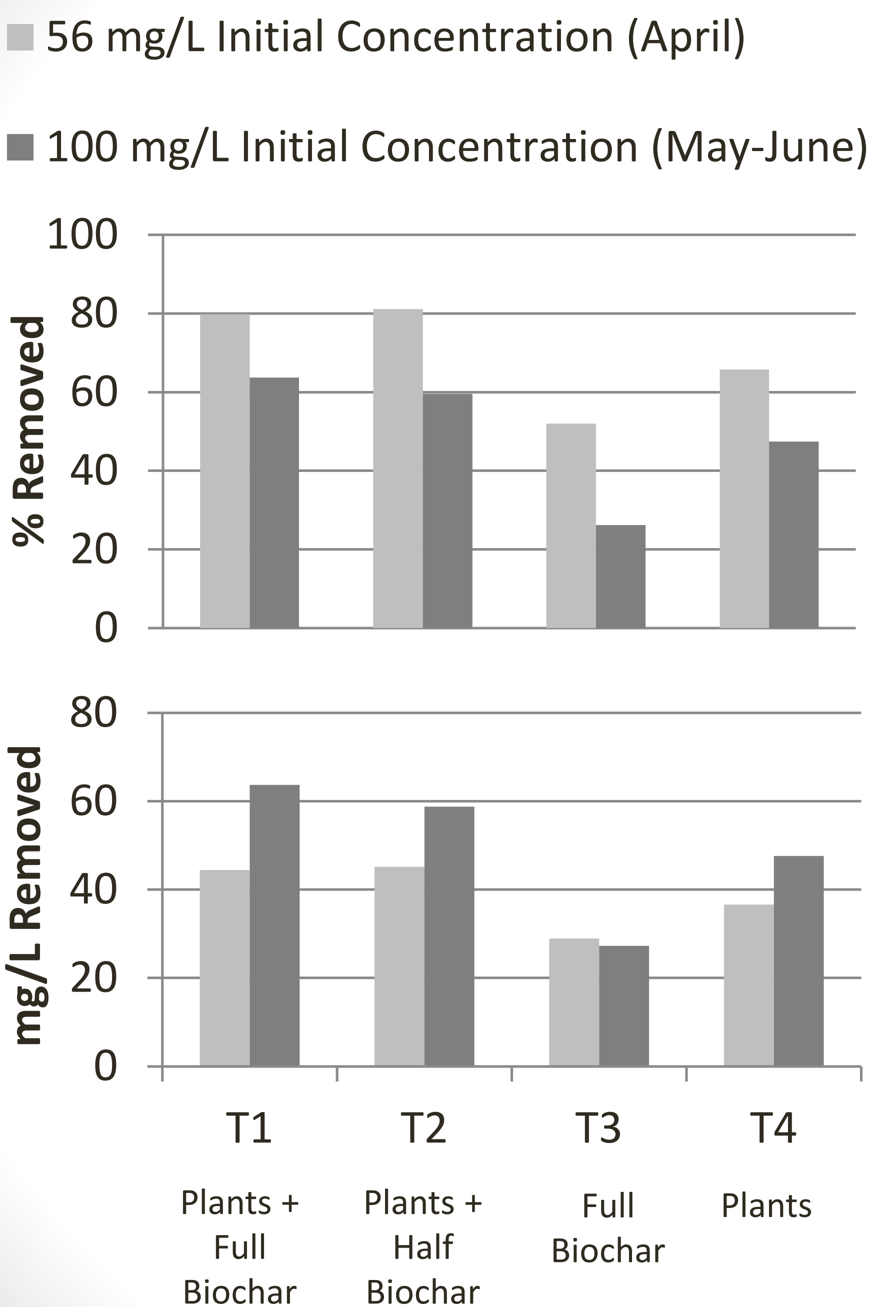
Equal to T2

29% more than T3

12% more than T4

- ✓ Removal of COD more than doubled in May/June for all tanks

Results - NH_4^+-N Removal



Overall T1 removed

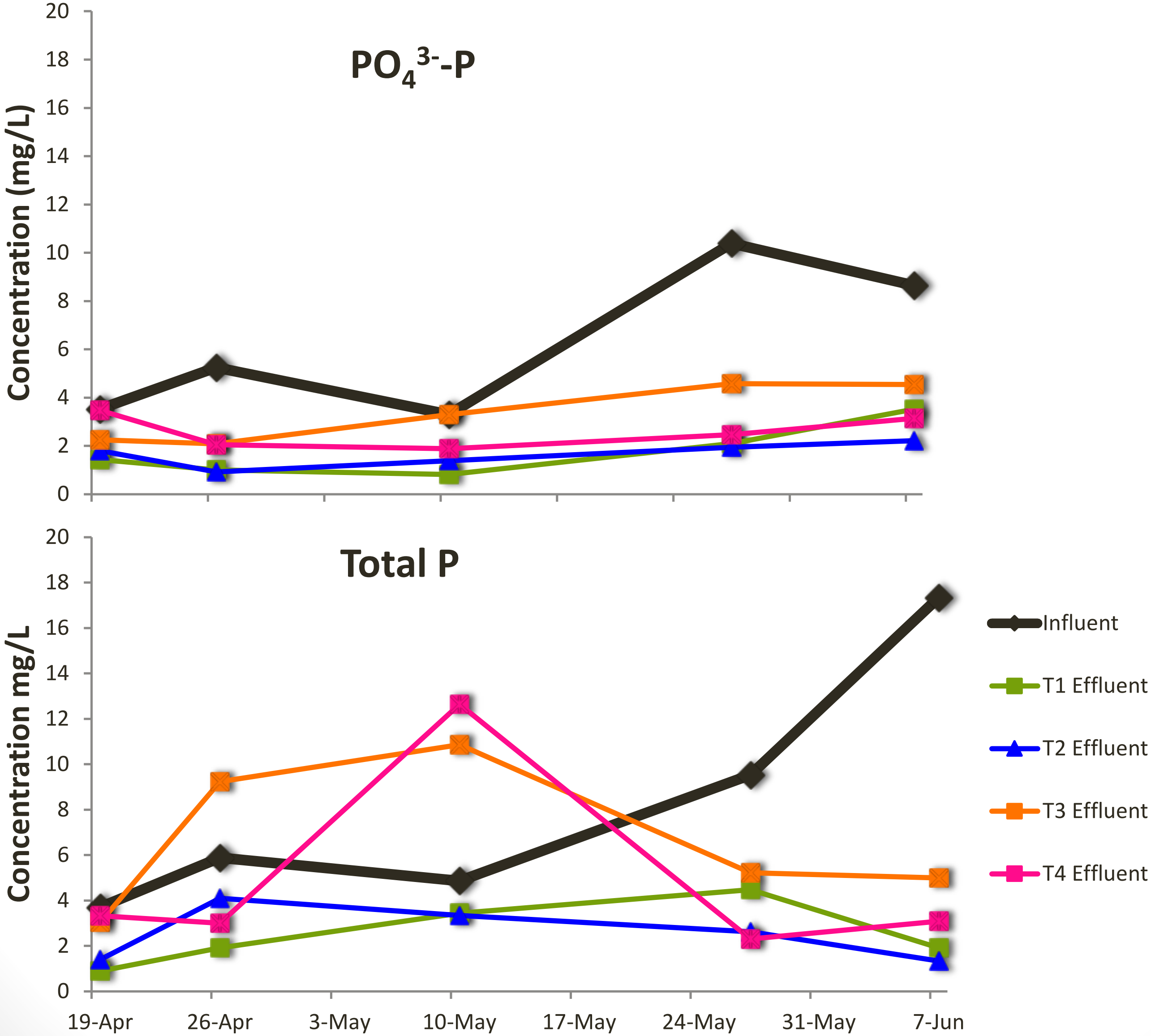
5.0% more than T2

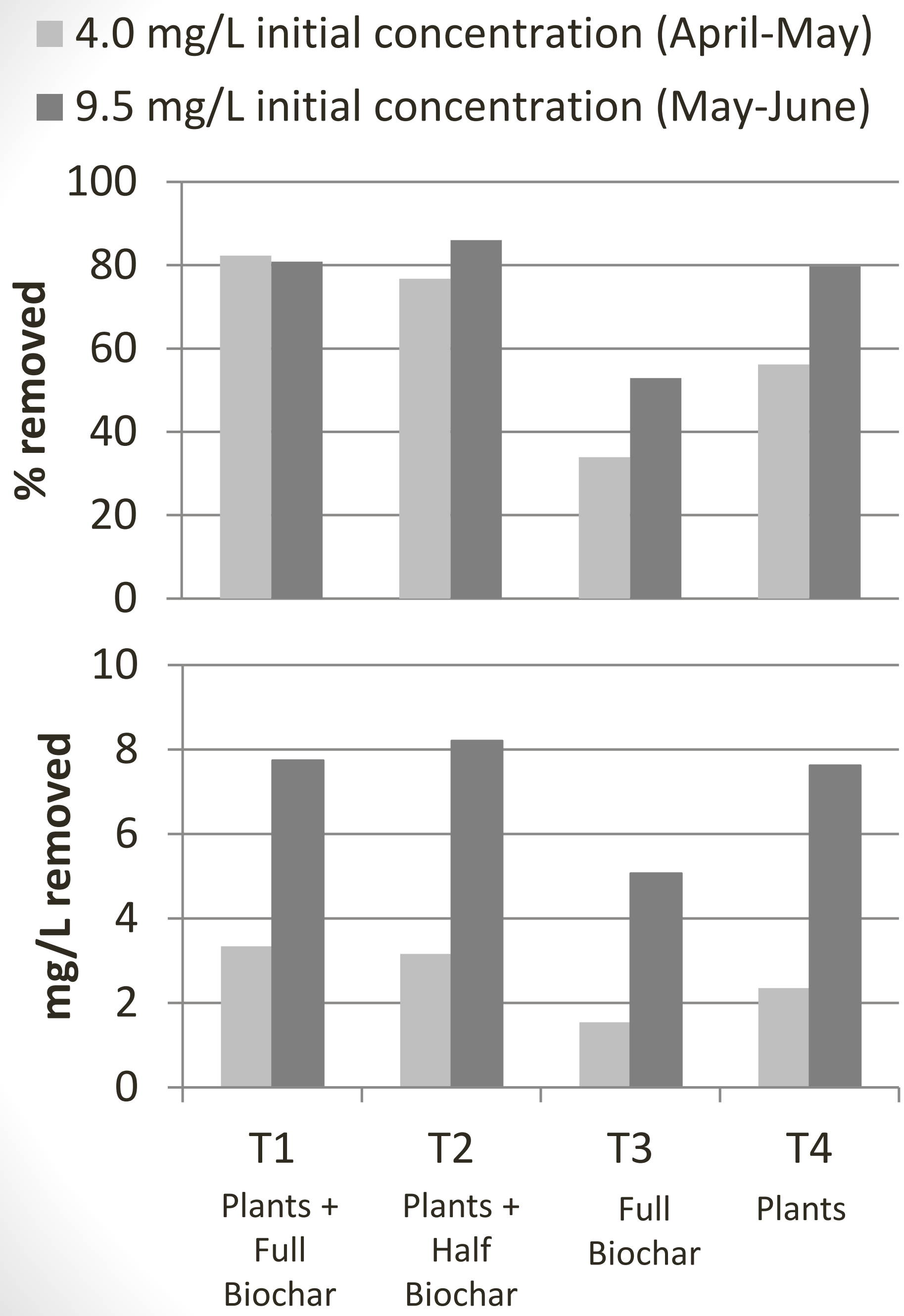
50% more than T3

23% more than T4

- ✓ Amount removed increased in all planted tanks in May-June, slightly lower in unplanted (T3)

Results – Influent & Effluent Total P and PO_4^{3-}-P





Results - PO_4^{3-}-P

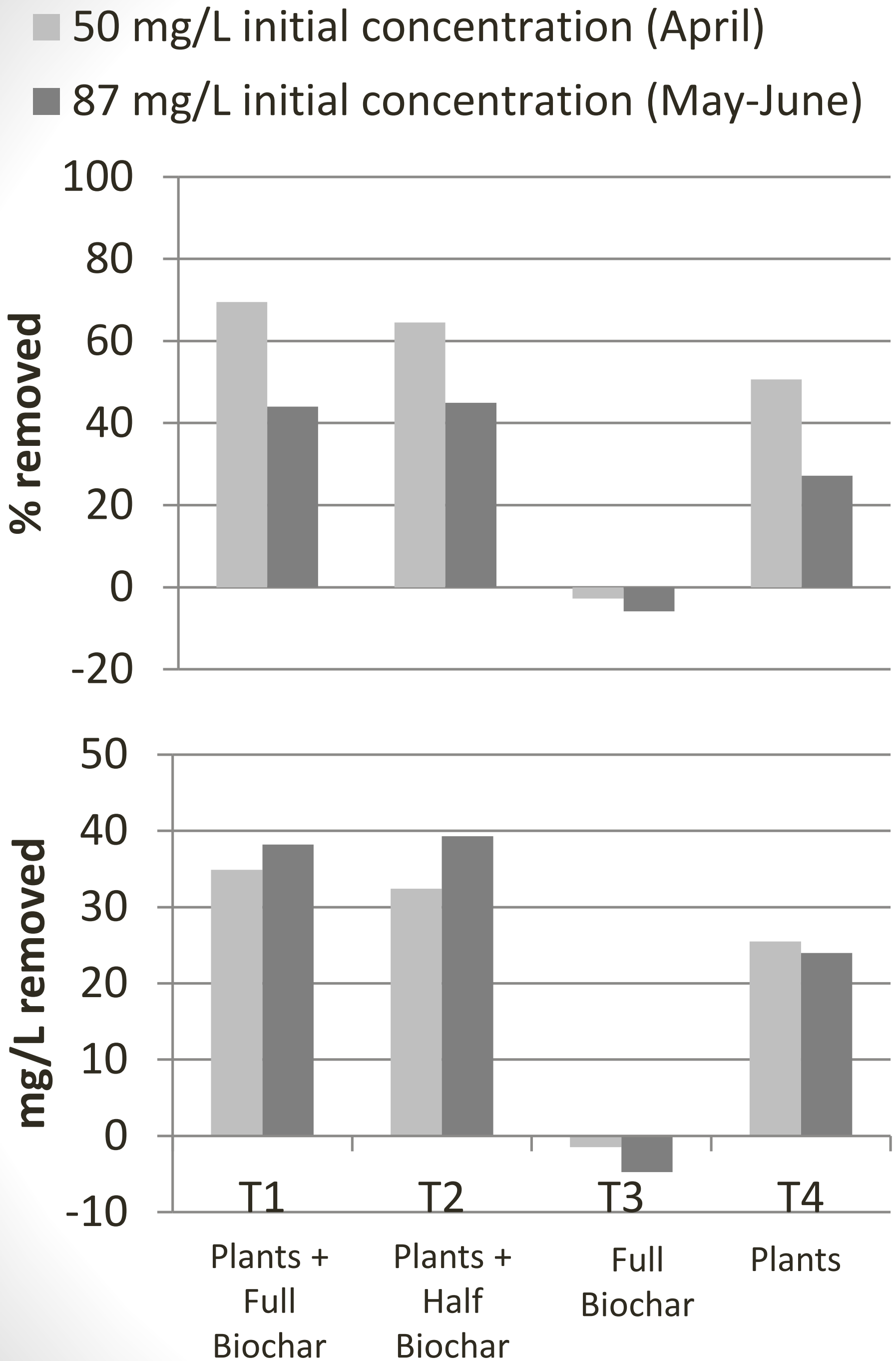
Overall T1 removed

Equal to T2

42% more than T3

13% more than T4

- ✓ T4 (no biochar) removed less in April than T1 and T2 (planted, biochar) but caught up to them in May-June
- ✓ Does biochar enhance plant removal or degradation of phosphate?



Results – K Removal

Overall T1 removed

Equal to T2

109% more than T3

33% more than T4

- ✓ K removal amount increased in planted biochar tanks (T1, T2) in May-June, but not in planted gravel tank (T4)

Conclusions

- Biochar increased plant tolerance of high nutrient concentrations and cold weather
- Biochar and plants together increased nutrients removal from swine wastewater over that of biochar or plants alone.
- Biochar + Plant > Plant alone > Biochar alone
- Doubling amount of biochar in tank made little difference
- Overall removal efficiency increased with increase in plant biomass and time

Further questions/research

- Biochar feedstocks, activation
- Biochar - wetland substrate characteristics
- More understanding of the role of microbes
- Field trials, long term trials

Thank You!

Questions?

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