Evaluating P Balance in P-Use Efficient Transgenic Romaine Lettuce Using Algae As an Alternative P Fertilizer

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Introduction

Phosphorus (P) is essential to all life because it is involved in fundamental biochemical functions. Thus, P fertilizer is in high demand in agriculture. This strong reliance on P may come at a great cost for humanity. First, only a few countries own the majority (~75%) of global phosphate rock reserves. This increases the uncertainty for farmers about long-term access to long-term affordable P (Elser et al. 2014). Second, P losses from field to fork to feces result in drinking water pollution that produces toxic algae blooms. Addressing these concerns requires improved P efficiency in crop production as well as the establishment of robust recycling pathways. This study evaluates two potential approaches for improving P sustainability: use of algae to capture lost P and be directly used as fertilizer (Wang et al. 2013) in combination with use of an engineered, P-efficient crop (AVP-1 transformed lettuce (Paez-Valencia et al. 2013).

Research Question: Is dry algae *Scenedesmus dimorphus* (with N:P=13:1 by mass) a good N fertilizer (compare to commercial fertilizer) and what is its optimum application rate for wild type versus AVP-1 transformed crops?

Methods

Preliminary results showed that setting fertilizer treatments based on algal P levels resulted in excessive N application and poor lettuce growth. So, in this study we established fertilizer levels based on algal N levels both with added additional P to generate a fertilizer N:P ratio within the optimal range for lettuce and without added P. We also maintained a treatment involving commercial fertilizer. Concentrations and ratios of added nutrients in the various treatments are shown in **Figure 1**.

We grew both wild-type and AVP-1 transformed lettuce with these fertilizer treatments to assess the nutrient use efficiency of the two strains and to compare their performance on conventional and algae fertilizers.

Each treatment had 8 replicates. Algae were ground and sieved and mixed with soil before planting seeds (6 seeds per pot; the seed first germinated was selected). P spikes and commercial fertilizer were split-applied through the whole growing period. Dry above and below ground plant biomass was assessed. Leachates were collected after watering every time. One pot from each treatment was randomly selected from the 8 replicates to perform P fractionation experiment (Hedley et al. 1982).

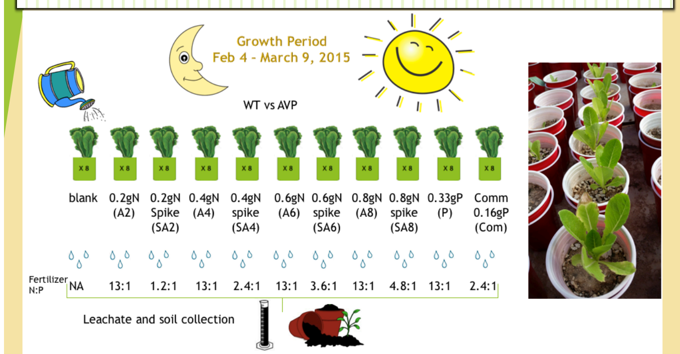

Fig. 1 Experimental set-up: wild type (WT) and AVP1 lettuce were grown under different treatments (control, 0.2, 0.4, 0.6, 0.8g algal N w and w/o spiking P, 0.33g algal P, and commercial fertilizer with 0.16g P).

Results

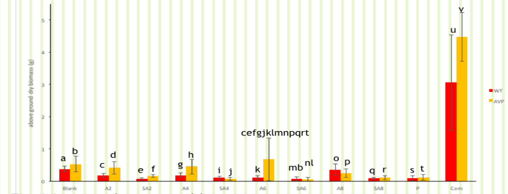

Fig. 2 Lettuce above ground biomass

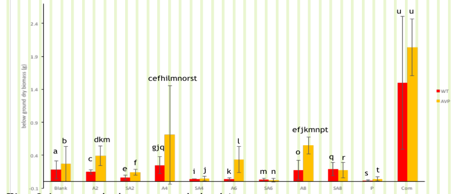

Fig. 3 Lettuce below ground dry biomass

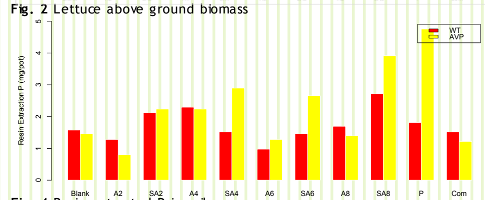

Fig. 4 Resin extracted P in soils

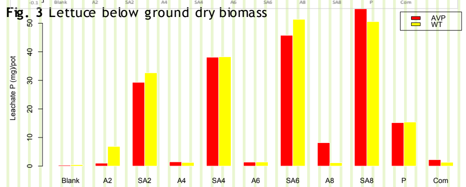

Fig. 7 Leachate TP from all treatments

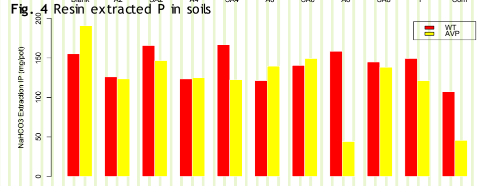

Fig. 5 NaHCO3 extracted IP in soils

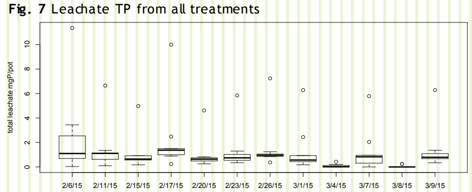

Fig. 8 Median and quartiles of leachate TP in algae treatments without spike

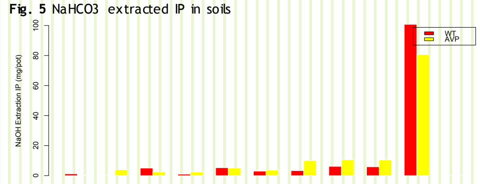

Fig. 6 NaOH extracted IP in soils

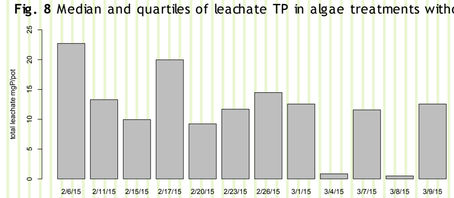

Fig. 9 Leachate TP combined from all algae treatments without spike

Discussion

- Dry algae is not as good as commercial fertilizer (neither N nor P): lettuce grown in commercial fertilizer treatment had the highest biomass and less P from leachate.
- High N:P in algae was due to the way of algal biofuel production that stressed algae with limited nutrients in order to obtain higher lipid yield.
- AVP-1 lettuce generally performed better than WT lettuce. Algae treatments with P spikes had higher TP in leachates.
- High N content (high N:P) in algae could be harmful for growing lettuce. 1. High pH + high NH4+ -> NH3; 2. Anaerobic condition. These two factors both could stunt root growth.
- High P leachate from algal treatments may due to the form of P is unavailable to lettuce.
- Major release of algal P in soil seems to happen in the first 10 days. However, as leachate was pooled from the 8 replicates, there was no statistical comparisons among treatments.

- Future research: pretreatment of algae to make P more available and N less harmful
  1. Grow algae in plant-favorable N:P, such as 2:1
  2. Different methods of pretreatment for harvested algae
  3. Use different algal species

References

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