California Leafy Greens Research Program
FINAL REPORT
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Developing nitrogen management strategies for leafy greens using soil health metrics

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Abstract
Production of lettuce is intensive, requiring high inputs, frequent cultivation, and heavy overhead and/or surface irrigation. These requirements make the implementation of techniques to build soil health, reduce greenhouse gas emissions and sequester soil carbon challenging. Increasing organic matter in lettuce production also has many potential co-benefits, such as increasing soil organic nitrogen (N) availability, reducing fertilizer N input, and improving crop and fertilizer N use efficiency, and reducing the greenhouse gas, nitrous oxide (N_2O). Currently limited data exist to validate and predict long-term outcomes associated with conservation management in leafy greens. This limits the ability to track and report progress towards reaching on-farm sustainability goals. In partnership with D'Arrigo California, we implemented a split-plot designed field experiment with treatments receiving N applications at grower's standard (GS) rate (290 lbs N ac-1), NRCS Nutrient Management Conservation Practice Standard (CPS) 590 rate (232 lbs N ac-1), and no N (control). In split fertilizer plots, compost was applied at a rate of 5 d.w.t/acre and a no compost plot. Soil, crop, and greenhouse gas data were collected over a period of 12 months. Results show that crop N uptake was only significantly different (p=0.03) between the GS rate and the no N treatments, while no difference was found between GS and CPS N rates. Regardless of N application rates, the addition of compost did not significantly increase crop N uptake. Cumulative N2O emissions were highest in the GS treatment (36.3 mg N2O-N m-2) and lowest in the No N with compost treatment (9.9 mg N2O-N m-2). All the treatments that received compost had lower N2O emissions compared to those without compost (N application alone). Our work also includes technical assistance training in the use of the COMET-Farm sustainability decision support tool.

Objectives

1) Evaluate the single season N impact of low-rate compost application on lettuce crop performance and soil health. Completion of the objective will improve grower recommendations concerning the integration of organic matter amendments into nitrogen management plans.

2) Improve the lettuce dataset for further calibration and validation of the DayCent biogeochemical model to predict long-term crop performance and soil health outcomes from conservation nutrient management scenarios. Completion of this objective will increase the usefulness of the USDA carbon management decision support tool COMET-Farm for the lettuce industry.

3) Provide technical training in the use of COMET-Farm, a USDA carbon management decision support tool, in lettuce production systems. Completion of this objective will provide the industry a tool to account for and document long-term N outcomes from compost application.

Materials and Methods

In partnership with D'Arrigo California, we carried out a replicated, two-level split plot field experiment that included three N application rates, grower standard (GS), Conservation Practice Standard (CPS) or No N, as the main factor and compost application at a rate of 5 d.w.t./acre as the secondary factor. The treatments were implemented over two cropping periods. Leaf (Lactuca sativa) lettuce, were grown over the 2021 season, harvested in May and September. Crop biomass and its N content in dry weight percent was determined by combustion analysis on a Costech EAS 4010 elemental analyzer. Microbial biomass was determined using chloroform fumigation. Gas measurements were made using in situ static chambers and analyzed on a gas chromatograph (Model 2014, Shimadzu Scientific Instruments). Mean cumulative area-based N_2O fluxes were calculated.

Results

- **Fresh weight biomass**
  Total fresh weight biomass yield was not significantly different across treatments($p=0.06$), but did differ by date ($p<0.5$). The GS treatment with compost had the highest mean yield during the first crop (82100 lbs $acre^{-1}$) whereas the GS only treatment had the highest during the second crop (56699 lbs $acre^{-1}$).

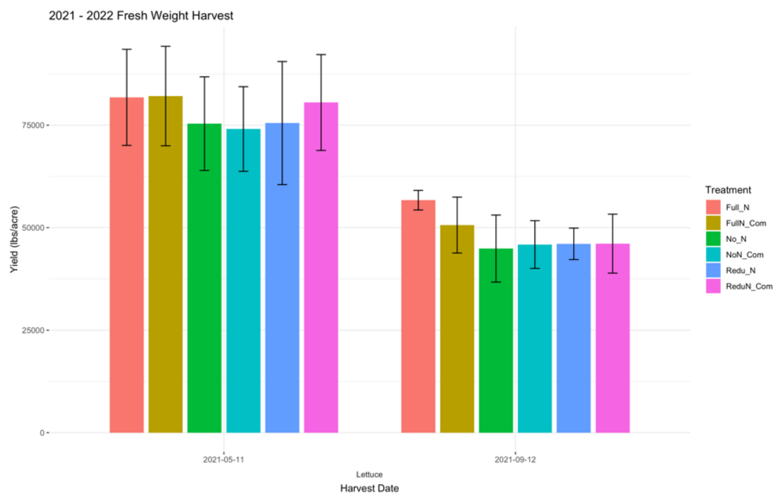

Figure 1. Fall 2021- Spring 2022 harvest shown as total fresh crop biomass by treatment. Error bars represent +- standard error of the mean.

- **Crop Nitrogen Uptake**
  There was no significant difference in crop N uptake under CPS compared to GS N rates (p=0.22). Compost did not significantly improve crop N uptake, regardless of the N application rates (p=0.16 for the CPS rate and p=0.99 for the GS rate).

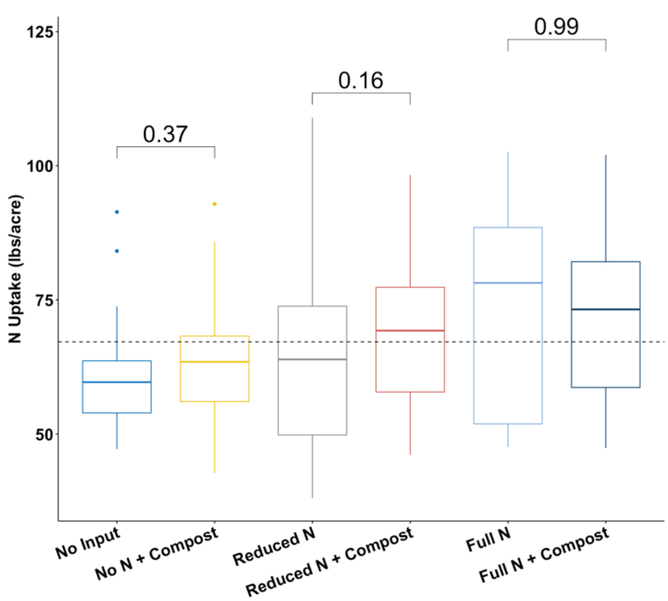

Figure 2. Boxplot showing total nitrogen uptake for combined 2022 lettuce harvest. Dotted line depicts mean value across all treatments.

- **Soil Organic Nitrogen**
  Microbial biomass nitrogen (MBN) did not significantly differ across treatments ($p=0.24$) but did significantly differ by depth ($p<0.05$), which was expected. The reduced N rate combined with compost had the highest MBN of all the treatments (15.3 mg N kg^{-1}), with the lowest level found at the depth increment 60-80 cm in the grower standard with compost (1.02 mg N kg^{-1}).

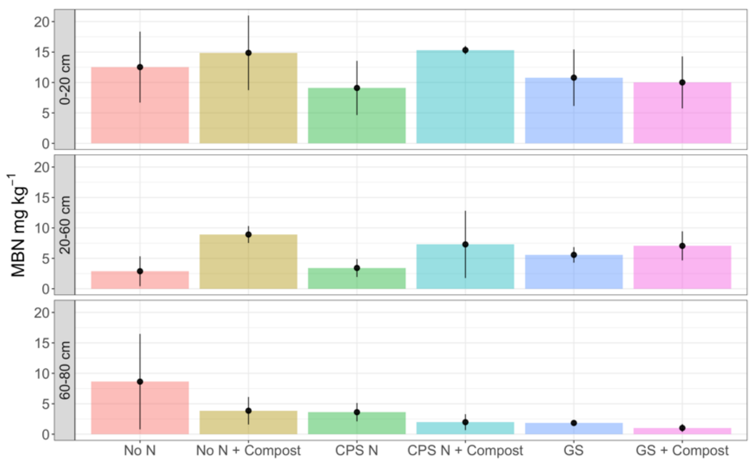

Figure 3. Average microbial biomass carbon and nitrogen at three measured depths (0-20 cm, 20-60 cm, 60 – 80 cm) for all treatments. Error bars represent +- standard error of the mean

- **Nitrous Oxide Emissions**
  For N_2O emissions, the only significant difference across all treatments was between the No N + Compost and GS treatments ($p = 0.032$); emissions were three times as high in the GS treatment compared to No N + Compost. All the treatments that received compost had lower N_2O emissions.

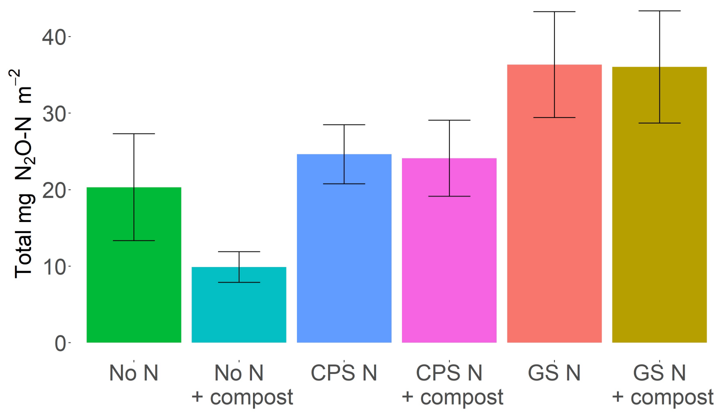

Figure 4. Cumulative mean daily N2O with standard error bars for all measurements collected in 2021.

Summary

Simple, conservation informed nutrient management techniques can be used in leafy green production without compromising crop performance. As our project has shown, when implemented, these techniques also have the added climate benefits of reducing GHG emissions and improving soil health. These results provide important data specific for central coast leafy green production and will allow for the validation of decision support tools aimed at sustainability tracking and reporting. Additionally, this project will help agricultural managers design and implement soil health improvements to support climate-smart agricultural practices while maintaining crop yield potential. To support these activities, we plan to offer stakeholders in the region hands-on training in the use of the COMET-Farm greenhouse gas and soil carbon accounting tool in February of 2023.