Compost Application to Alfalfa

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Introduction:
The term 'soil health' has become a common term in agricultural research and management. While it may be familiar to test soil for chemical properties, like nutrients, salinity, and pH, soil health also considers soil physical characteristics – like compaction, aggregation, and water infiltration – and biological characteristics – like soil respiration, active carbon, and nitrogen mineralization. These properties influence the soil's ability to function, and enhancing these properties can improve soil functioning to grow crops and produce ecosystem services. We often relate soil health to management practices like crop rotation, cover cropping, reduced tillage, and compost amendment because these have been shown to increase soil functioning in agricultural landscapes. They are also some of the practices that are financially incentivized by the CA Department of Food and Agriculture Healthy Soils Program.

Compost is decomposed organic matter from plants or animals. Plant-derived composts – like green waste compost – have a high carbon-to-nitrogen ratio (C:N), which is the relative amount of carbon and nitrogen in the material. Animal-derived composts have a low C:N. The C:N ratio is important because it affects microbial metabolic functioning and plant-available nitrogen. There is a regulatory framework for diverting green waste from landfills to make compost. In 2014, AB 1826 was passed in California, which required businesses to recycle organic wastes and jurisdictions to set up organic waste recycling programs to divert green waste from landfills. In 2016, AB 1383 established organic waste reduction targets (75% reduction by 2025, compared to 2014). The bill also required jurisdictions to do education and outreach. Green waste diversion is expected to reduce greenhouse gas emissions by 4 million metric tons per year and increase food recovery by 20 percent. Agricultural land could serve to receive green waste compost recovered by this regulatory framework.

With a Healthy Soils Program grant, we evaluated the application of green waste compost to established alfalfa fields for effects on soil quality, alfalfa yield, and greenhouse gas emissions. Alfalfa occupies a large footprint on the California agricultural landscape (over 600,000 acres), and its production offers soil health benefits, including biological nitrogen fixation, facilitation of soil microbial activity, and organic matter inputs from large root systems. Alfalfa, however, has a high phosphorus (P) and potassium (K) requirement, and as a perennial, 'high-traffic' crop, fields may suffer from poor physical traits (e.g. compaction, impaired water infiltration). Our objectives were to learn whether green waste compost changes soil nutrient status or other soil health characteristics, alfalfa yield or quality, or greenhouse gas emissions from the system.

Methods:
The study was conducted on commercial fields in Yolo (75 acres) and San Joaquin (25 acres) counties in California's Central Valley. The soil type at the Yolo location was a Myers clay (approximately 50 percent clay) and had approximately 1.5 percent organic matter in the top foot of soil. The soil type at the San Joaquin location was a Peltier mucky clay loam with approximately 8 percent organic matter in the top foot of soil. Green waste compost was broadcasted over established alfalfa at rates of 3 and 6 tons per acre. Treatments were made in the fall/winter of 2020, 2021, and 2022 ahead of forecasted rainfall, which incorporated the compost. The experimental design at both locations was a randomized complete block design with three replicates. Soil samples from the top foot were collected with hand augers in the fall of each year ahead of compost application. These samples were analyzed for a suite of macro- and micronutrients, pH, salinity, and organic matter. We also measured soil structural indicators, including aggregate fractionation (large and small

macroaggregates, microaggregates, and non-aggregated sand and silt particles), saturated hydraulic conductivity (using a Meter Group Saturo Infiltrometer), compaction (using a Spectrum FieldScout SC 900 meter), and soil cracking. Soil cracking was assessed in late summer/early fall of each year by counting the number of soil cracks visible and contacting a 32-foot transect, across 3 replicate transects. Alfalfa yield was measured from four replicate quadrats (1-m^2) per plot, from four cuttings per season and scaled to annual yield based on the number of cuttings made by the growers. Yield samples were also analyzed for forage quality. Greenhouse gas emissions were determined from monthly chamber measurements. The concentration of CO_2, CH_4, and N_2O was measured using a Shimadzu GL 14APS gas chromatograph. Data were analyzed by analysis of variance (ANOVA) and Tukey's mean separation.

Results:

Compost application resulted in no statistically significant differences in total carbon (TC) or total nitrogen (TN) across years or sites (Fig. 1). There were also no changes in soil phosphorus (P), but compost amendment increased soil potassium (K) at the San Joaquin location in 2021 and 2023 (Fig. 2). The San Joaquin soil was low in K, and the crop was not otherwise fertilized. The compost analysis showed that the product was roughly 1 percent K; thus, the 3-ton compost rate added approximately 50 lb of K per acre. Based on the amount of change in soil K and the compost analysis, we attribute the increase in soil K to the compost. Additionally, there was a trend for alfalfa tissue K to improve with compost amendment at the SJ site (Fig. 3), and this translated into higher yields (Fig. 4). There were no differences in tissue TN, P, or sulfur (S) in any year at either location (data not shown).

Greenhouse gas emissions (CO_2, N_2O, CH_4) did not change as a result of compost amendment in any year or at either location (Fig. 5), indicating that the carbon that was added by the compost was not respired from the system. There were higher carbon dioxide (CO_2) emissions at the SJ compared to the Yolo site, which we attribute to the inherently higher carbon of the SJ soil. Additionally, we observed that the soil acted as a methane (CH_4) sink. This is noteworthy because CH_4 is a stronger greenhouse gas than CO_2.

There were no significant differences among treatments in soil physical traits, like wet sieving (2023), infiltration (2024), or compaction (2023) at either location (Fig. 6). At the Yolo location, soil cracking occurs due to the high clay content; however, we found no reduction in soil cracking with compost use (Fig. 7). We evaluated a suite of forage quality parameters in 2022 and 2023 and found no differences in quality at either location (Fig. 8).

Summary:

We found that green waste compost application had little to no impact on soil chemical and physical traits, greenhouse gas emissions, and alfalfa yield and quality. The exception was an increase in soil K and alfalfa yield at the San Joaquin site. We attribute the increased yield to the higher soil available K, since fertilizer was not applied over the duration of the trial and soil K was deficient. Future research should evaluate effects when compost applications are made over more than three years. Green waste compost is a relatively cheap soil amendment, but the cost of transporting it to farms can be high. In 2021, we estimated that material plus hauling cost was approximately $27/ton and spreading was an additional $10/ton. Our results suggest potential benefits to soil fertility where fertilizers are not otherwise applied; however, financial incentive programs will likely be important for widespread adoption.

Based on our experiences working on this project, we have the following guidance for growers interested in applying green waste compost. The highest demand for compost is in the fall. To ensure availability, growers should aim to purchase compost in the spring or summer and store it on-site until fall. Ordering the compost in spring or summer also tends to result in a higher quality product delivered (i.e. less trashy). Timing compost application can be a challenge (i.e. after all harvests but before soil gets too wet), so having the compost already on-site may help in getting it applied more readily.

We thank growers, Garrett Mussi (SJ) and Duane Chamberlain (Yolo), for cooperating with us on these trials. We acknowledge the CDFA Healthy Soils Program for financial support.

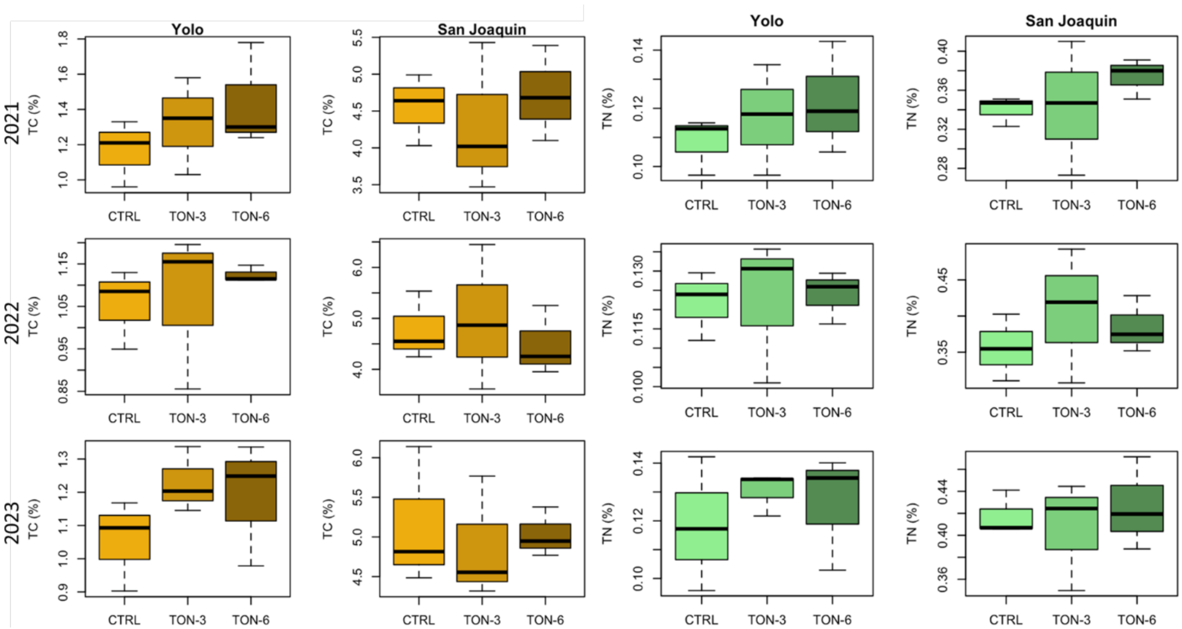

Figure 1. There were no differences in soil carbon (TC) or nitrogen (TN), but there was an observed trend for C to increase at the Yolo site, which has inherently low soil organic matter.

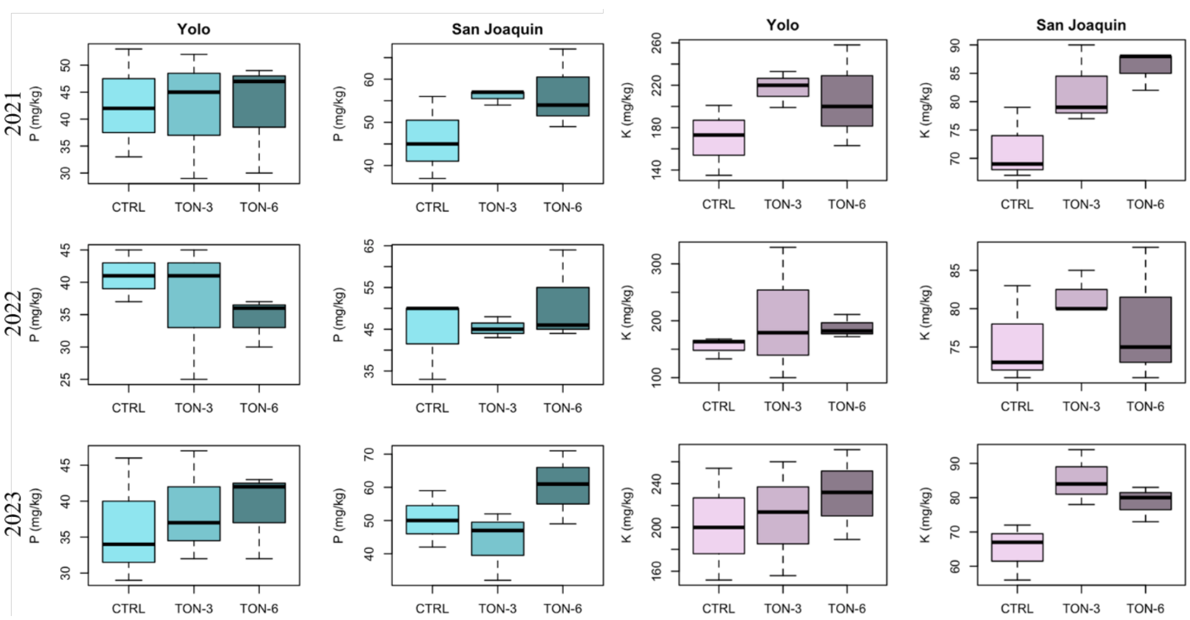

Figure 2. There were no changes in soil phosphorus (P) with compost treatment. Compost increased soil potassium (K) at the SJ site (2021, 2023), where soil K was inherently low.

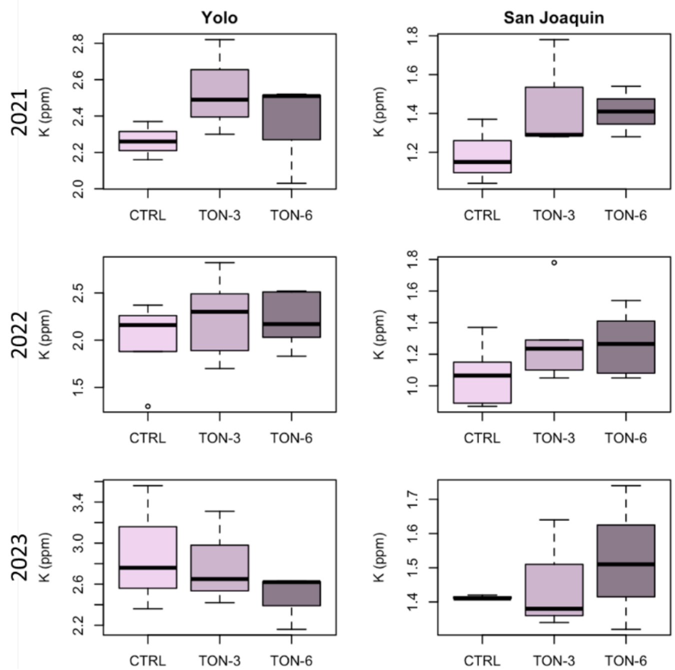

Figure 3. There was a trend for alfalfa tissue K to increase at the SJ site, which we attribute to the higher soil K.

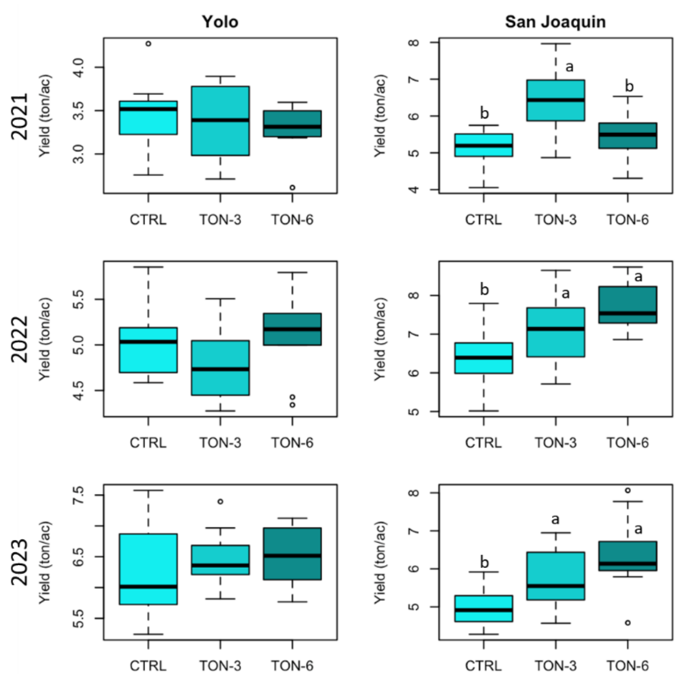

Figure 4. Compost amendment did not statistically improve alfalfa yield at the Yolo site, but yields did improve at the SJ site, which we attribute to improved K availability.

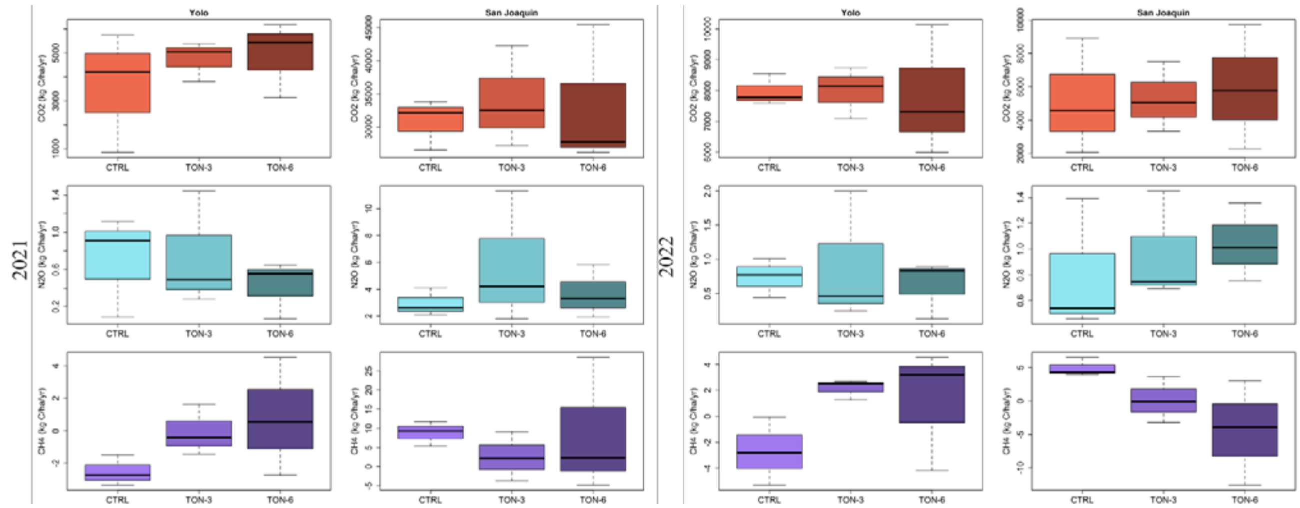

Figure 5. There were no statistically significant differences in greenhouse gas emissions with compost amendment.

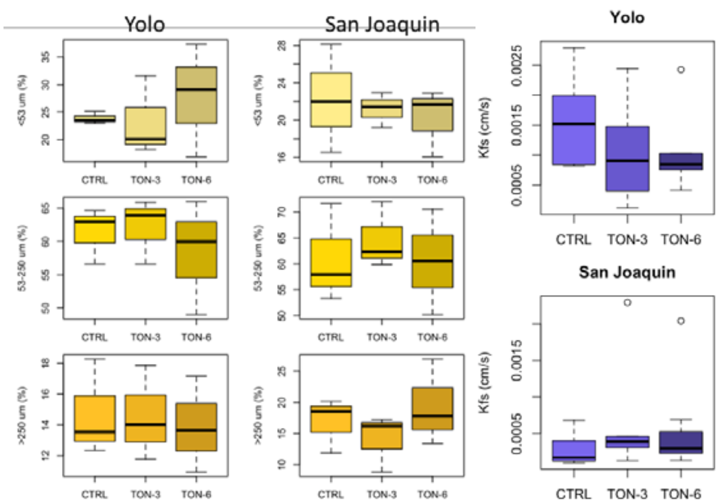

Figure 6. There were no differences in soil physical traits, like wet sieving (2023, yellow), infiltration (2024, purple), or compaction (2023, data not shown).

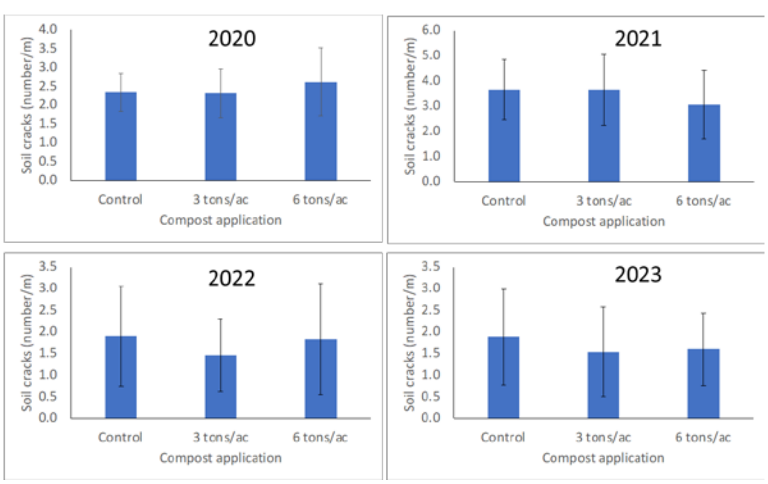

Figure 7. Soil cracking occurred at the Yolo location, but compost amendment did not reduce incidence of cracking.

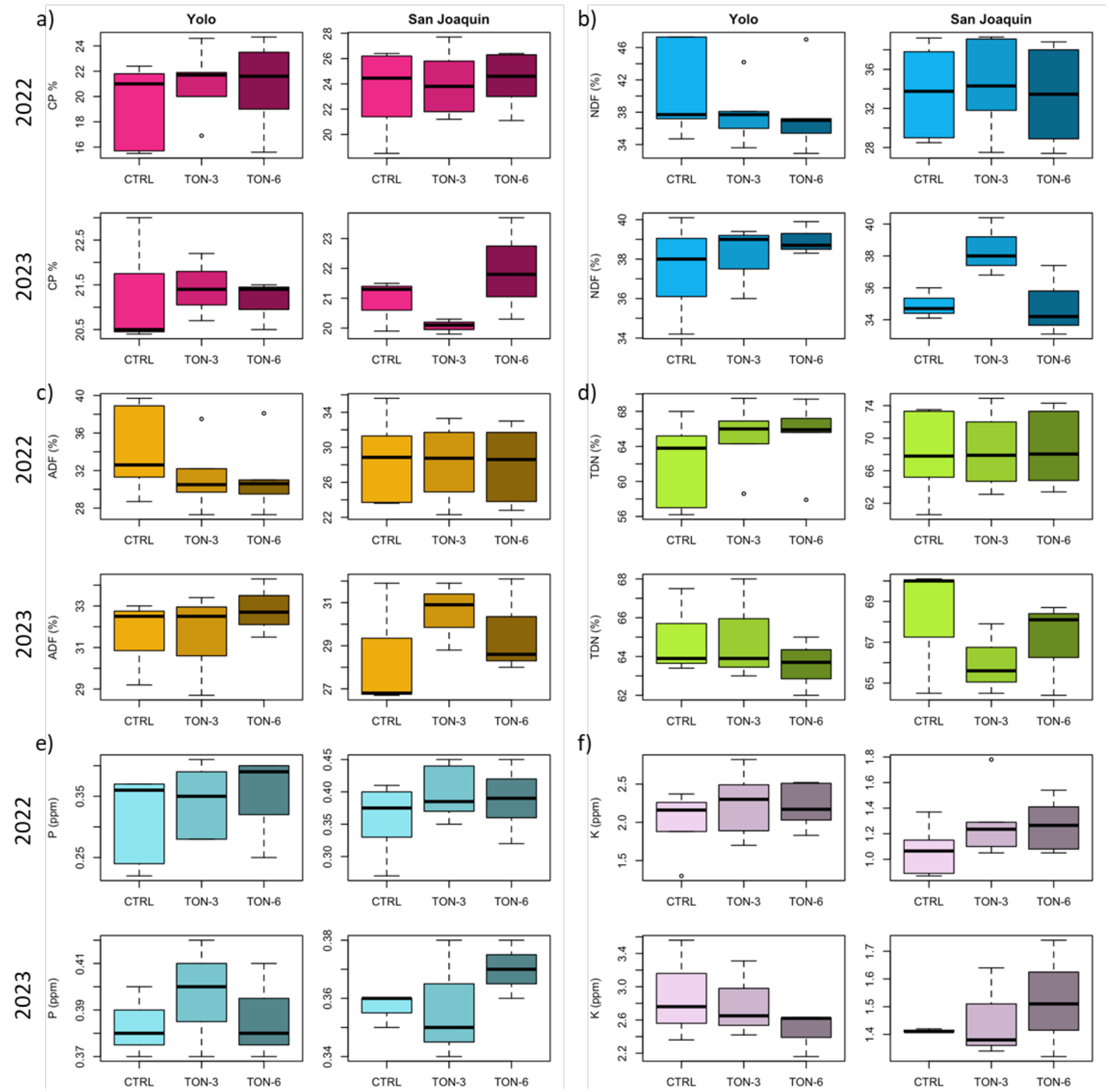

Figure 8. There were no differences in forage quality parameters across sites or years.