COMPOST APPLICATION IN CALIFORNIA TOMATO CROPPING SYSTEM

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ABSTRACT

With the implementation of California Assembly Bill (AB) 341 the availability of composts such as green waste (GW) and co-composted green waste and food waste (FW) as a soil amendment is increasing. The use of those organic amendments in agricultural production systems has been recommended as an effective strategy to make full use of organic waste and improve soil health. However, little information is available to tomato growers to reassess N inputs from using GW and FW. This study was conducted to assess the impact of GW and FW on N availability in tomato cropping systems using chemical fertilizer N inputs and evaluate potential adjustments in N management guidelines for N fertilization rates. Crop yield, plant N uptake, soil N availability, and nitrate leaching potential under the practices of GW or FW in tomato systems were measured. In addition, laboratory studies of the same compost materials were conducted to understand N mineralization kinetics as affected by different temperatures in different soils to gain a more general understanding of the fate of N in compost inputs in a broader range of soils.

MATERIALS AND METHODS

Field site descriptions and agronomic management

The field experiments were conducted at the UC Davis Russell Ranch Sustainable Agriculture research site and grower fields in Central Valley. In the Russell Ranch site (RR), the soil is classified as Rincon silty clay loam, a fine monmorillonitic, thermic Typic Haploxeralf. This site has been in a tomato-corn rotation since 2013 with corn in even years and tomato in odd years. Subsurface drip irrigation with mineral fertilizers (i.e., fertigation) was implemented in 2014 and represents industry norms. In grower's sites (MR1 in year 1 and MR2 in year 2), the soils are classified as Brentwood silty clay loam, a fine monmorillonitic, thermic Typic Xerochrepts and Yolo silt loam, a fine-silty, mixed, non-acid, thermic Typic Xerorthent. The grower's sites have been in a cucumber-sunflower-tomato rotation during the past few years. The fields are equipped with subsurface drip irrigation.

Compost/Fertility management and experimental design

At the RR site, 16 experimental treatments were set up as a split-plot randomized complete block design with three blocks (replicates). The treatments include two compost types (GW or FW) X three compost rates (0, 4 tons/acre or 8 tons/acre) X two fertilizer N levels (0 or 100% of recommended N rate). In addition, different compost application rates combined with corresponding reduced N rates were also selected by replacing N from the fertilizer with compost sources: 85% of recommended N rate X compost (GW or FW at the rate of 0 or 4 ton/acre) and 70% of recommended N rate X compost (GW or FW at 0 or 8 ton/acre). Two consecutive seasons of treatments were conducted in this site. Composts were commercially purchased and hand spread evenly on the soil surface and disked in with standard equipment to a depth of 10-15cm in spring for year 1 and in fall for year 2. See Table 1 for compost characteristics. The FW compost was produced by co-composting 5% food waste and 95% urban yard waste. The GW was 100% urban yard waste.

In the grower's site, 5 experimental treatments were set up as randomized complete block design with three blocks (replicates). The treatments include two compost types (GW or FW) X three compost rates (0, 4 tons/acre or 8 tons/acre). Composts were applied by standard equipment (i.e., spreader) and disked in to a depth of 10-15cm in the fall for year 1 but were applied by hand and disked in in the fall for year 2.

Soil sampling and analysis

Soil samples were collected to a depth of 0-15 from four composite borings from each plot with a 1.83-cm diameter steel corer before and after fertigation events and approximately monthly during the remainder of the year. Inorganic N (nitrate (NO_3^-) and ammonium (NH_4^+)) was measured by extracting 10 g of well-mixed soil with 40 mL of 0.5 M potassium sulfate solution, and by analyzing the extracts colorimetrically for NH_4^+ and NO_3^- using a Shimadzu spectrophotometer (Model UV-Mini 1240).

Nitrate leaching potential determination

Resin bags were buried 30 cm deep over the winter rainy season to determine nitrate leaching potential from the highest application rate (8 tons/acre) of FW and GW composts and in control plots at the Grower's site and the same compost treatments in the 100% N plots at the Russell Ranch site. The resin bags were made by filling nylon stockings with 50 g NO_3^- specific ion exchange resin (AmberLite™ PWA 5, Dow Chemical Co., Waterfall City, Midrand). After the resin bags were removed from the ground in March 2020, the resin was extracted with 150 mL of 1M potassium chloride (KCl). The extracts were analyzed colorimetrically for NO_3^- following the same protocol and spectrophotometer use as mentioned above (Doane and Horwath, 2003).

Yield measurements

In both years, tomatoes were harvested in late August in both sites. Yields, biomass and N content of the harvested plant parts were measured. In both regular treatment plots and ^{15}N subplots, three adjacent tomato plants were randomly selected, and the aboveground biomass were separated into fruits and residues. Fruits were then sorted into green, red and rotten tomatoes and weighed.

Lab incubation and sampling

A laboratory aerobic incubation was conducted with two soils collected from the upper 15 cm in a conventional system (CMT) and a conservational system (OMT) at the Russell Ranch Sustainable Agricultural Facility and one soil collected from the upper 15 cm in California Central Valley. Soil samples were passed through a 2-mm sieve, mixed thoroughly to ensure uniformity and stored in a 4 °C cold room until the experiment began. FW and GW composts applied in this experiment were ground to pass through a 1-mm sieve before mixing with soil. The composts were added at the rate of 24 g dry weight kg^{-1} soil (oven dry basis).

Table 1 Basic properties of soils and composts in this study

Materials	pH	TN ($g\ kg^{-1}$)	TC ($g\ kg^{-1}$)	NO_3^--N ($mg\ kg^{-1}$)	NH_4^+-N ($mg\ kg^{-1}$)
RR soil	7.13	1.47	15.2	11.0	1.13
MR soil	6.72	1.52	9.33	9.05	6.42
Conventional treatment soil (CMT)	6.43	1.12	10.2	18.8	1.07
Conservational treatment soil (OMT)	6.50	1.85	15.8	61.0	0.98
Arbuckle soil (AS)	5.8	0.64	4.23	2.48	0.19
FW	7.65	18.6	229.7	121.9	1.89
GW	7.75	18.9	223.8	95.1	1.89

The experiment was a completely randomized block design and each treatment was replicated three times. The incubation experiment consisted of 36 treatments with a multifactorial combination of two composts (FW or GW), two N fertilizer levels (urea at 100 mg N kg^{-1} or control, non-urea), and three different soils (OMT, CMT or AS) under three temperature levels (10°C, 20°C, or 30°C). The incubation experiment lasted 28 days under three temperatures in environment-controlled rooms at the University of California, Davis. 20g dry weight equivalent of soil was placed in 120 ml specimen cups which were placed in 1L mason jars. In order to ensure gas exchange and maintain soil humidity, each mason jar was covered by a lid with a hole in the middle plugged by a sponge during the whole incubation process. To guarantee a homogenous distribution of fertilizer in soil, fertilization treatments received a dose of 100 mg N kg^{-1} oven dry soil in water solution and sprayed onto the soil in layers by a syringe to ensure the final moisture content of 60% of soil water holding capacity (WHC). Besides, soil was weighed every 2-3 days and adjusted with distilled water to keep the moisture to 60% WHC. On days 0, 3, 7, 14, 21 and 28, soil samples were collected for monitoring the dynamics of N_2O, NO_3^--N and NH_4^+-N. Soil net N mineralization rate was calculated as the difference in inorganic N between two time points and t temperature sensitivity coefficient (Liang et al.,2016), Q_{10}, was calculated using: $Q_{10}= (R_2/R_1)^{10/(T_2-T_1)}$

Where R_1 and R_2 are the mineralization rate of N at T_1 and T_2, respectively. T_1 and T_2 are incubation temperatures (°C).

RESULTS & DISCUSSION

Soil N availability as affected by compost application

Figure 1 shows the soil NO_3^- content at the time of tomato harvest (August) and eight months after harvest (April in the following year). The results showed that significantly higher NO_3^- occurred in soil after the fields had been fallowed for eight months following harvest. This is likely due from normal N mineralization and accumulation during the fallow season. However, in grower's site I, it was surprising to find that less NO_3^- occurred in the compost treatments compared with the control after the eight months of fallow. The similar results were also found in the 70%N treatment when food waste was applied. The detected NO_3^- in April reflects a balance of net N mineralization and N losses through gas emissions and leaching. Therefore, further data is needed to determine if less NO_3^- in the composts especially food waste treatments was caused by nitrate leaching or less N be mineralized.

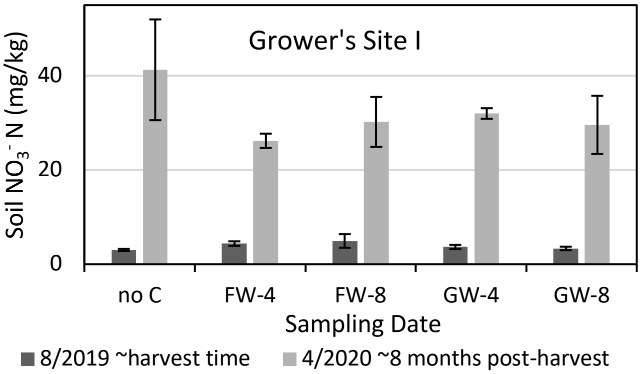


Figure 1: Soil N availability (mainly in the form of NO_3^-) at the time of harvest and eight months after harvest for both Russell Ranch and Grower sites.

Nitrate leaching potential in different compost treatments

The NO_3^- leaching potential of the control plots was compared to the highest application rates of compost (8 tons/acre) based on the NO_3^- concentrations extracted from the ion exchange resin bags that were buried over the winter rainy season. These data are shown in Figure 12. The results showed that the plots with no compost had the lowest rates of NO_3^- leached, while the plots that received GW compost had the highest NO_3^- leaching potential among all the plots. Interestingly, the leaching potential of FW compost applied in both sites was similar to the controls, suggesting that FW compost likely immobilized N, unlike GW compost treatments.

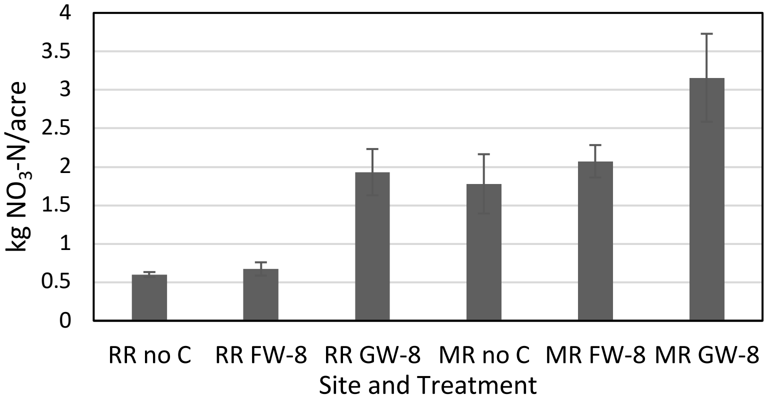
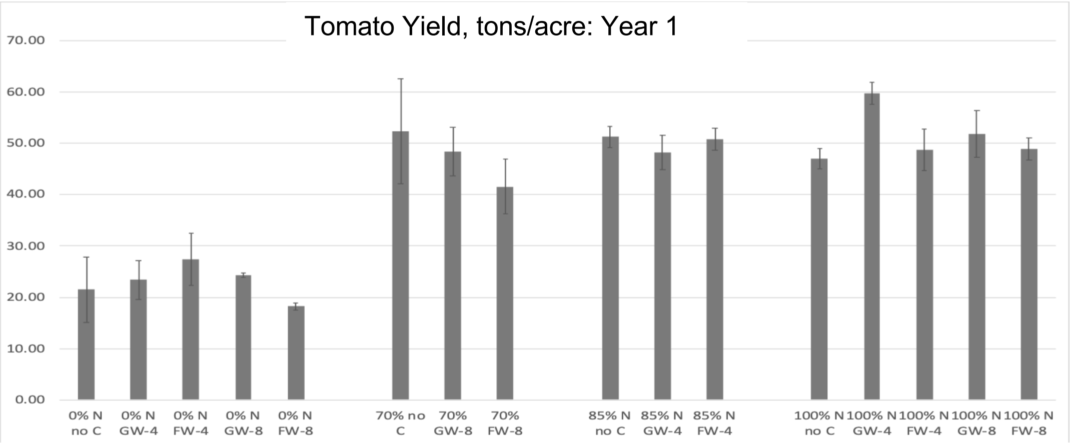


Figure 2: NO_3^- leached from the top 30 cm of soil in the control and highest rate of compost application plots at Russell Ranch and Grower's site II.

Crop yield in different compost treatments

There are varying results between the effect of compost types and compost rates on crop yield at RR site, but tomato yield did increase with increasing input rates of N fertilizer compared to no N addition (Figure 3). However, the yields in the treatments of 100%N were not higher than in the 85%N treatments, suggesting that fertilizer N inputs can likely be decreased by up to 15% of the recommended rate to maintain the same yield. Figure 4 shows tomato yield from MR site for the 2 compost types at 3 application rates. Similarly, the data vary between compost types and rates, although the yield from the treatment of 4 tons/acre of GW was significantly higher at the second grower's site than the first site. The higher yield in the treatment of 4 tons/acre of GW was also found in RR site when 100%N was applied.



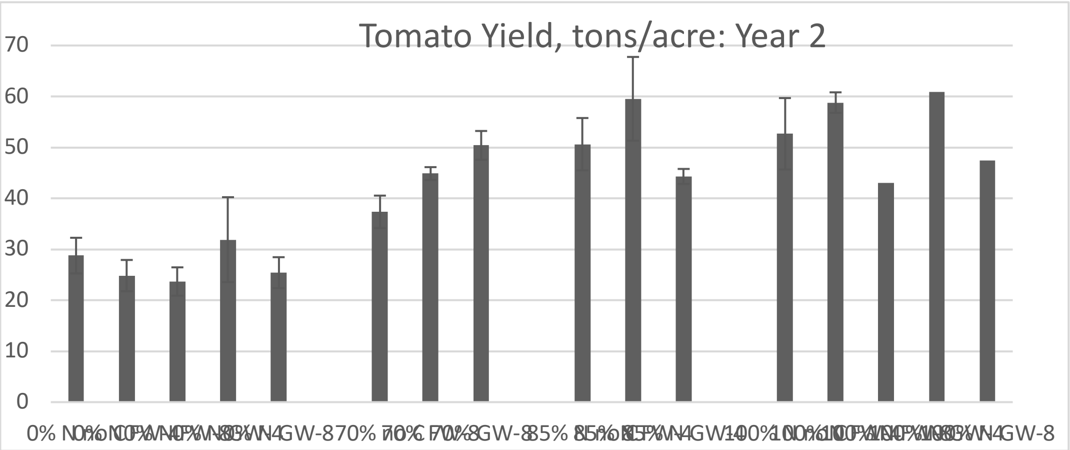


Figure 3: Tomato yield for two consecutive years at RR for the 2 compost types (FW and GW) at 3 application rates (no compost, 4 tons/acre, and 8 tons/acre), and 4 N levels (0%, 70%, 85%, and 100%) of the recommended amount. The error bars represent standard error.

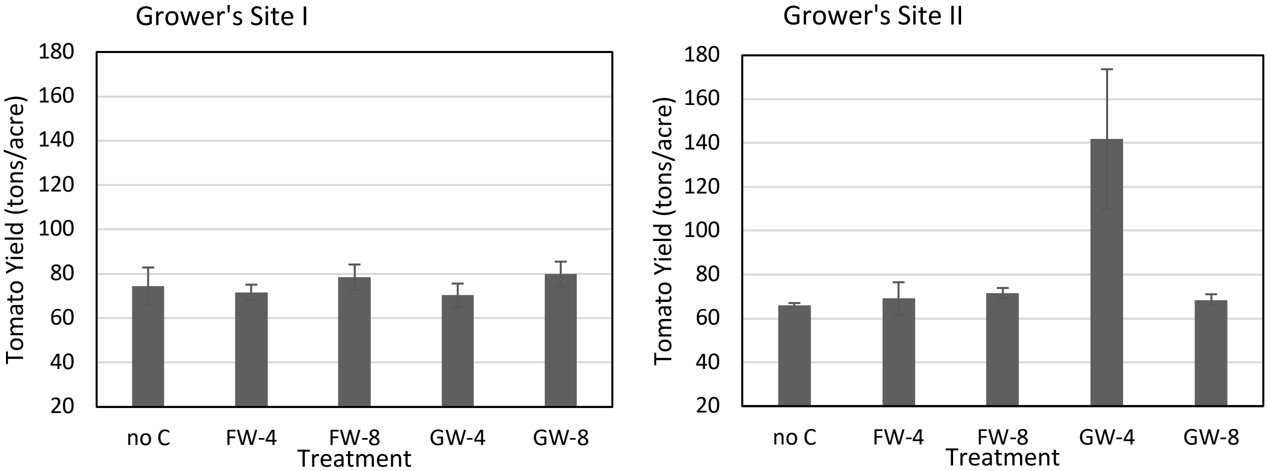


Figure 4: Tomato yield at the two MR sites for the 2 compost types (FW and GW) at 3 application rates (no compost, 4 tons/acre, and 8 tons/acre). The error bars represent standard error.

Net N mineralization rate and its temperature sensitivity

Table 2 shows the net N mineralization rates (NMR) during the 28 days incubation. As the temperature increased from 10°C to 30 °C, the NMR significantly increased in all three soils, except in AS soil incubated with FW alone, in which less N was mineralized in 30°C than other temperature levels. Generally higher NMR was found in the urea treatments than the non-urea treatments. This is due to the hydrolysis of urea which released inorganic N (NH_4^+) during the incubation. Significantly higher NMR was found in the OMT soil than the other two soils. Unexpectedly, less N was net mineralized in the treatments of compost compared with the control (no compost) in the CMT and OMT soils. This is likely due to the addition of composts promoted soil N immobilization or the use of compost impaired microbial activities and therefore less N was mineralized. However, in the AS soil, the application of compost promoted net N mineralization. This is likely because the AS soil has very low fertility (low soil C and N, Table 4) and the addition of C enriched amendments promoted soil microbial activities that mineralized more N. Lower NMR was also found in the FW than in the GW treatments when compost was applied alone. This result was consistent with the field study which found less NO_3^- leaching potential and soil/compost derived plant N in the FW treatments compared with the GW application.

The response of N mineralization to temperature change was defined as Q_{10}, as shown in Table 6. Among the three soils, the Q_{10} values were slightly higher in the OMT than CMT and AS soils. The Q_{10} value varied greatly at different temperature ranges, with higher Q_{10} values found when the temperature increased from 20°C to 30°C than from 10°C to 20°C. This result indicated that N was mineralized faster in the higher temperature. The application of compost in the CMT and OMT soils had a trend to decrease Q_{10} values compared with the control (no compost). When the temperature increased from 20°C to 30°C, the response of N mineralization to temperature was more sensitive in the FW treatment than the GW treatment. However, the application of urea significantly decreased the temperature sensitivity of soil N mineralization compared to the control. Higher Q_{10} value was found in the GW+urea than in the FW+urea treatments.

Table 2 Soil N mineralization rate and Q_{10} under different temperature and compost treatments

Soils	Treatment	Net mineralization (mg -N kg^{-1} d^{-1})			Q_{10}	
		10°C	20°C	30°C	10-20°C	20-30°C
Conventional soil (CMT)	Control	-0.07	0.12	0.35	-1.78	2.99
	FW	-0.15	0.08	0.22	-0.5	2.79
	GW	-0.1	0.14	0.32	-1.42	2.38
	Urea	2.34	2.59	2.66	1.11	1.03
	FW+Urea	2.2	2.15	2.46	0.98	1.11
	GW+Urea	2.28	2.41	2.67	1.06	1.15
Organic soil (OMT)	Control	0.04	0.58	1.2	15.13	2.06
	FW	-0.28	0.35	1	-1.25	2.82
	GW	-0.23	0.48	1.14	-2.05	2.4
	Urea	2.07	2.55	3.18	1.23	1.24
	FW+Urea	2	2.56	2.99	1.28	1.17
	GW+Urea	2.01	2.31	2.85	1.15	1.23
Arbuckel soil (AS)	Control	-0.08	0.14	-0.2	-1.88	-1.43
	FW	-0.19	0.32	0.61	-1.72	1.88
	GW	1.06	1.16	1.4	1.1	1.2
	Urea	2.45	2.75	-0.8	1.12	-0.29
	FW+Urea	1.99	2.19	0.79	1.1	0.36
	GW+Urea	1.85	1.96	2.04	1.06	1.04