Fertigation management for tomato production in saline soils

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Abstract. *Nutrient availability is a major problem for vegetables grown in saline environments. In tomatoes, calcium deficiency can lead to blossom-end rot during periods of reduced plant transpiration. The objective of our study was to evaluate different management strategies to increase calcium availability in saline soils, including calcium fertilization and irrigation water acidification. Four treatments were compared in a commercial processing tomato field: two calcium-based fertilizers (calcium ammonium nitrate and calcium thiosulfate), water acidification, and a conventionally used nitrogen fertilizer (urea ammonium nitrate). Treatments were applied through a sub-surface drip system and replicated four times in a randomized complete block design. Results indicated that the calcium thiosulfate treatment produced the highest yield (66.2 tons/acre; $p<0.002$) in 2009. However, no significant difference was obtained among treatments in 2010 (average of 37 tons/acre). Acidification resulted in higher incidence of blossom-end rot. Fertigation strategies did not influence the total soluble solids (Brix of 5.5-6.5^o) and root dry weights.*

Keywords. Tomato, fertigation, salinity, calcium, blossom-end rot.

Introduction

Tomato constitutes the second most important vegetable crop grown worldwide after potato with about 100 million tons produced annually on 9.1 million acres. The United States (U.S.) is the second largest producer of processing tomatoes behind China (FAO, 2008). About 96% of the nation's produce is grown in California, and particularly in the San Joaquin Valley (SJV) and Sacramento Valley (USDA, 2009; Hartz 2008).

In the western SJV where soils are predominantly saline-sodic, growers have traditionally produced cotton because of its ability to tolerate high salinity levels (Maas and Hoffman, 1977). However, in response to declining prices, cotton production has been decreasing steadily and replaced with higher value vegetable crops, such as tomatoes and onions, grown with more efficient irrigation systems, i.e. drip.

However, such transition represents new challenges. Vegetable crops are more sensitive to salinity and more susceptible to disease/deficiency when grown under saline-sodic soil conditions (Letey, 2000). In tomatoes, studies have shown that low calcium (Ca) availability in saline-sodic soils may lead to blossom-end rot (BER) (Swift, 1997; Sherf and Woods, 1979), which is a very common problem in the Westside SJV. Yield of tomatoes start decreasing when soil EC reaches 2.5 dS/m. High sodium (Na) content in soils reduces Ca uptake by plants. Furthermore, leaching of salts is much slower under drip irrigation, which can prevent optimal crop development. These problems can be addressed by supplying additional Ca fertilizer to increase soil availability or by reducing the soil pH and exchangeable sodium through acidification.

Therefore, the overall goal of this study was to evaluate different management strategies to increase calcium availability in a commercial processing tomato field characterized by high salinity levels. We compared the effects of soil calcium fertilization and irrigation water acidification on yield, incidence of blossom-end rot (BER), total soluble solids (Brix index), and root dry weights.

Materials and Methods

The research study was conducted in a commercial processing tomato field owned by AZCAL Farms, Lemoore, CA. The field was characterized by a lethent silt clay soil which exhibited salinity levels in the range of 2-8 dS/m at 0-1 ft depth. The study was conducted during two growing seasons in 2009 and 2010.

The experimental design consisted of four fertigation treatments replicated four times in a randomized complete block (RCB) design. Therefore, there was a total of 16 plots, each extending over a length of 300 ft and covering five 5.5ft-wide beds (Figure 1). The fertigation treatments were as follows:

- T1- Ammonium Nitrate (AN)
- T2- N-Phuric + Ammonium Nitrate (US + AN)
- T3- Calcium Ammonium Nitrate (CAN)
- T4 – Calcium Thiosulfate + Ammonium Nitrate (CTS + AN)

Treatments 3 and 4 included calcium (Ca)-based fertilizers; Treatment 2 was used for acidification of the irrigation water and Treatment 1 represented the conventionally used nitrogen (N) fertilizer.

The total study area, encompassing 80 field rows, was equipped with a separate sub-surface irrigation system installed to accommodate the four different fertigation treatments. Four separate manifolds were used to apply the various treatments. In 2009, acidification of the irrigation water was performed using a peristaltic pump on which the flow could be adjusted to attain a pH of 6.0-7.0. In 2010, N-Phuric was added using a Mazzei® injector. The pH was checked daily during irrigation events with a pH meter. The AN, CAN, and CTS fertilizers were stored in large tanks and injected through the sub-surface drip system. The total Nitrogen and

Calcium application rates during the growing seasons in both years were 250 lbs N/ac and 125 lbs Ca/ac, respectively. Irrigation scheduling was based on the California Irrigation Management Information System (CIMIS) data and a flow meter was installed to calculate the amount of irrigation water applied.

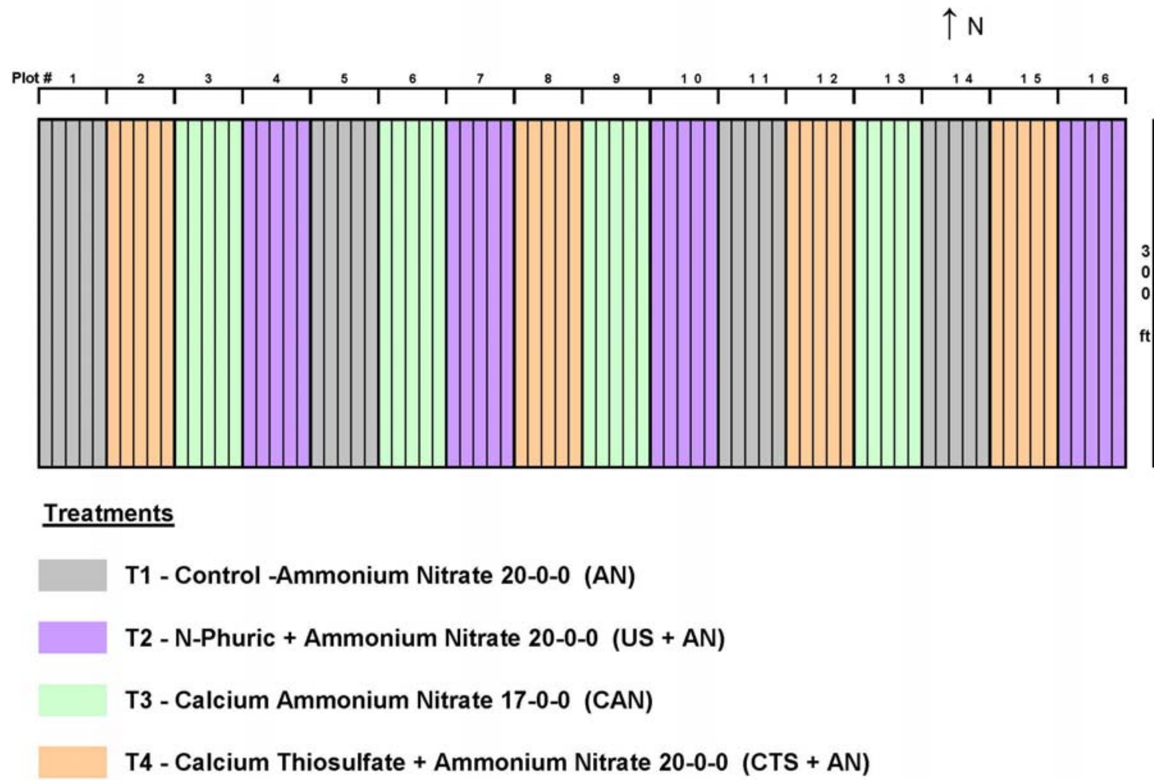

Figure 1. Field experimental layout and fertigation treatments

Plant, fruit, and soil samples were collected during both growing seasons. Leaf, petiole and fruit samples were collected at full bloom, one inch diameter fruit, appearance of first red, and at harvest. Sampling was performed at three random locations in each plot. All tissue samples were analyzed for calcium concentration. Fruit samples were analyzed for total soluble solids (expressed as degree Brix), titratable acidity and calcium concentration. Tomato harvest was performed at nine sampling locations within each plot. Tomatoes were sorted by reds, greens, breakers and blossom-end rots for yield calculations and the incidence of BER for each treatment was determined by measuring the number of fruits showing visible symptoms.

Root samples were collected at harvest and oven-dried to obtain dry mass weights. Soil sampling was performed pre-plant, post-harvest and during plant tissue sampling. Soils were analyzed for moisture, saturation percentage (SP), sodium adsorption ratio (SAR), electrical conductivity (EC) and pH (Gavlak et al., 2003). Soil sampling was performed in every plot at three locations (head, middle and tail) and at four depths (0”-6”, 6”-12”, 12”-18” and 18”-24”).

Data collected for each growing season was subjected to analyses of variance using the univariate general linear model available for a randomized complete block design in the SPSS® software (SPSS, 2010).

Results and Discussion

Figure 2 shows the average marketable yields obtained for tomatoes harvested in 2009 and 2010. Results show that there was a significant difference among treatments (p=0.002) for the marketable yield in 2009. Treatment 4 (Calcium thiosulfate + Ammonium Nitrate) provided the highest yield with 66 t/ac. However, yields obtained with Treatments 1 (Control with Ammonium Nitrate), 2 (water acidification with Ammonium Nitrate), and 3 (Calcium Ammonium Nitrate) were not significantly different. In 2010, fertigation treatments did not have an effect on yields (p=0.340).

It is noteworthy that tomato yields in 2010 were lower than those obtained in 2009, which could be attributed to differences in variety, seeding procedure and climatic conditions. Tomatoes were transplanted in 2009 whereas seeds were used in 2010. Additionally, the year 2009 was characterized by hot and dry days during much of the growing season; climatic conditions were wetter and cooler in 2010.

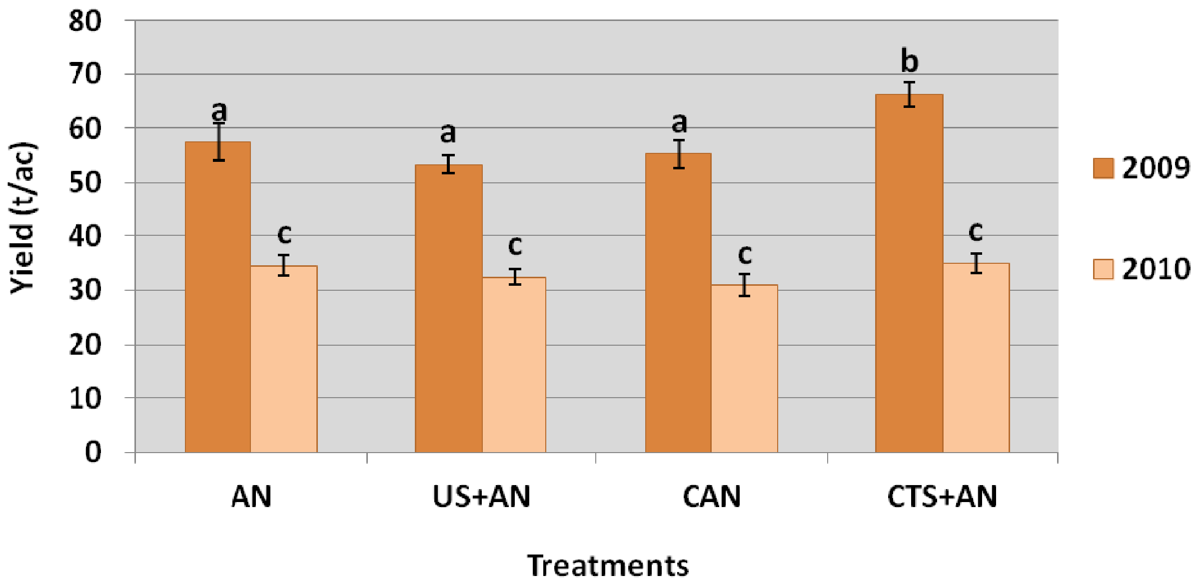

Figure 2. Average marketable yield of tomatoes (t/ac) in 2009 and 2010 (letters indicate significant difference at p =0.05).

The number of blossom end rots (BER) in tomatoes was significantly different among treatments in both 2009 (p=0.009) and 2010 (p=0.008) (Figure 3). In 2009, higher occurrence of BER was observed in tomatoes fertilized with Ammonium Nitrate only (Treatment 1) and in Treatment 2 where irrigation water was acidified to reduce soil pH. In 2010, the latter treatment resulted in significantly higher incidence of BER compared to Treatment 4 where tomatoes were fertigated with Calcium Thiosulfate and Ammonium Nitrate. It is important to note that the second-year study was characterized by a greater occurrence of blossom-end rot tomatoes.

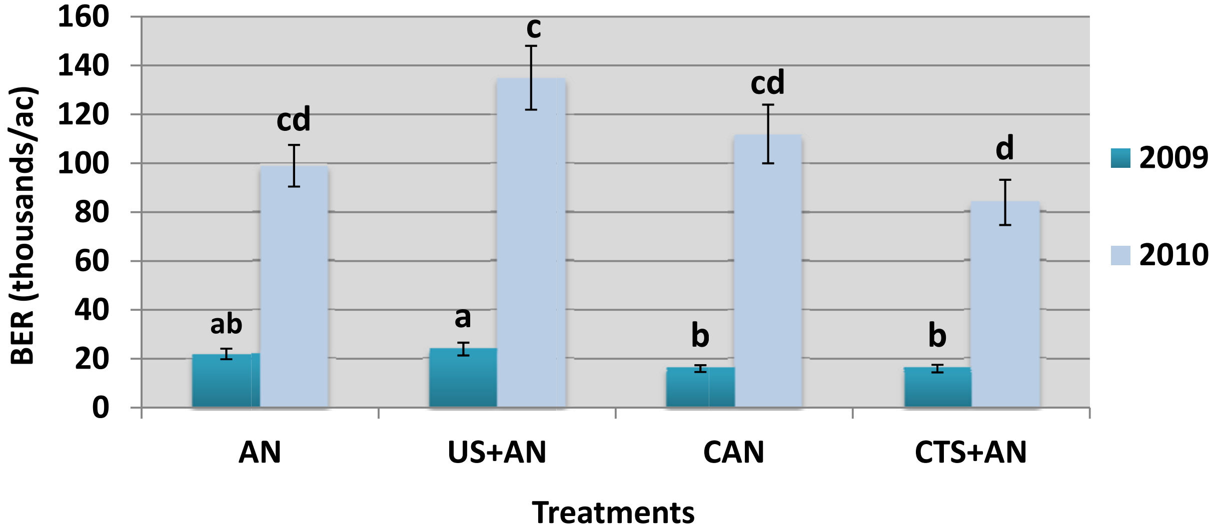

Figure 3. Incidence of blossom-end rot tomatoes in 2009 and 2010 (letters indicate significant difference at p =0.05).

Table 1 shows the total soluble solid levels (TSS) obtained at harvest for tomatoes in 2009 and 2010. TSS was expressed as degree brix and was computed on three tomatoes for each replicated treatment. Results indicated that the fertigation treatments did not affect the total soluble solids of tomatoes in both years ($p>0.05$) (Table 1). The average brix levels were 6.5^{o} in 2009 and 5.5^{o} in 2010.

Table 1. Average degree Brix at harvest for 2009 and 2010

Treatment	2009	2010
AN	6.4	5.3
US+AN	6.7	5.3
CAN	6.5	5.8
CTS+AN	6.4	5.6

The dry weights of roots taken at harvest were not significantly affected by the fertigation treatments in both years ($p>0.05$) (Table 2). Root weights averaged 16.3 g in 2009 and 10.0 g in 2010; and were statistical greater during the first-year study.

Table 2. Average dry weight (g) obtained on 12 tomato roots in 2009 and 2010.

Treatment	2009	2010
AN	18.2	8.1
US+AN	15.3	11.3
CAN	13.8	11.5
CTS+AN	17.9	8.9

Conclusion

- Tomatoes fertilized with Calcium Thiosulfate (T4) resulted in highest yield in 2009. No differences in yields among treatments was observed in 2010.
- Tomato yields in 2010 were lower than those obtained in 2009, which could be attributed to differences in variety, seeding procedure (transplants in 2009 and seeds in 2010) and climatic conditions.
- In 2009, higher occurrence of BER was observed in tomatoes fertilized with Ammonium Nitrate only (T1) and where irrigation water was acidified to reduce soil pH (T2). In 2010, tomatoes grown under T2 also showed higher incidence of BER when compared to tomatoes produced with Calcium Thiosulfate (T4).
- There was a higher incidence of BER in 2010 when compared to 2009.
- Total soluble solids and root dry weights did not differ with any fertilizer treatment. Greater dry root weights was observed during the first-year study.

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