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Effects of Sulfur Fertilization on Tomato Production

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Two field studies were conducted to determine the effect of S fertilization on tomato (*Lycopersicon esculentum* Mill.) yield and foliar S concentration. The soil had very low S content (<30 ppm) and 1.5% organic matter. Fertilizer sources were: 1) ammonium nitrate (AN; 34% N) at a rate of 300 lb/acre of N; 2) AN + potassium sulfate (PS; 23% S and 55% K) at rates of 300 + 343 lb/acre of N and S; 3) ammonium sulfate nitrate (ASN; 26% N and 14% S) at a rate of 300 + 343 lb/acre of N and S; and 4) a non-treated control. Muriate of potash (60% K) was used to balance total K amounts in each treatment to ensure that this nutrient was under non-limiting conditions. Plots treated with either rate of AN or non-treated had the lowest foliar S concentration, ranging between 0.55% and 0.53%. However, plots treated with S-containing fertilizers increased foliar S concentration when compared with the non-treated control and AN-treated tomatoes. Average S concentration was about 0.74%, which was 40% higher than the concentration in non-treated control plots. There were no significant marketable yield differences in plots treated with either AN + PS or ASN. Average marketable yield ranged between 27.5 and 28.2 ton/acre in the S-treated plots. In contrast, average yield in the AN-treated plots was 18.7 ton/acre, which was 44% and 42% less than the yields in the AN + PS and ASN-treated plots. These results suggest that soil analysis should be performed in tomato fields before planting to determine appropriate S application rates.

Sulfur is an essential plant nutrient required for the synthesis of the amino acids cysteine and methionine, proteins, and enzymes. It has been shown to play an important role in yield and quality of crops (Heeb et al., 2006; Pavlista, 2005; Rhoads and Olson, 2000). This element occurs in the soil in both organic and inorganic forms. In most soils, over 90% of S is in the diverse organic forms (Tabatabai, 1984). The majority of plants absorb S through the roots in the inorganic sulfate (SO_4) form, although limited amounts can be absorbed through the leaf stomata as the gas form SO_2.

Tomato production in west-central and southwest Florida typically occur on deep Spodosols (fine sand) with low organic matter content (<2%) and therefore inherently low in organic and inorganic S. In the past, S was supplied indirectly through other fertilizers such as triple superphosphate and deposition from the atmosphere. However, during the past two decades, as the composition of fertilizers changed to high-analysis and S-free products, crop production intensified, and SO_2 emissions decreased, S deficiencies have become a serious problem (Ceccotti et al., 1997). Sulfur deficiencies are often confused with other deficient elements such as N.

It has been suggested that to achieve high yields and to minimize S leaching, rates of S fertilizer should be recommended on the basis of available soil S and crop requirements (Scherer, 2001). In Florida, the sufficiency range for tomato (*Lycopersicon esculentum* Mill.) has been estimated between 0.3% and 0.8% S on the dry weight basis (Olson et al., 2006). A previous tomato study found that S sources (ammonium sulfate vs. ammonium thiosulfate) had similar effect on tomato yield (Susila, 2001). The same study determined that fine sandy soils were inefficient in supplying enough S for 6 weeks of growth, and preplant application of S produced lower leaf S concentrations than in those treatments where S was applied through drip (Susila, 2001). More studies are needed to confirm those results and to compare the effect of other S sources in tomato. Therefore, the objective of this study was to determine the effect of S fertilization on tomato yield.

Materials and Methods

Two field trials were conducted between Fall 2006 and Spring 2007 at the Gulf Coast Research and Education Center of the University of Florida in Balm. The soil was a sandy, siliceous, hyperthermic Oxyaquic Alorthod with 1.5% organic matter and pH 7.3. The soils was very low on S content (<30 ppm), as revealed by soil tests performed 4 weeks before transplanting. Fertilizer source treatments were: 1) ammonium nitrate (AN; 34% N) at a rate of 300 lb/acre of N; 2) AN + potassium sulfate (PS; 23% S and 55% K) at rates of 300 + 343 lb/acre of N and S; 3) ammonium sulfate nitrate (ASN; 26% N and 14% S) at a rate of 300 + 343 lb/acre of N and S; and 4) a non-treated control. Muriate of potash (60% K) was used to balance total K amounts in each treatment to ensure that this nutrient was under non-limiting conditions.

The treatments were applied 21 d before transplanting on two 3-inch-deep bands separated 14 inches apart on bed tops. Planting beds were 32 inches wide at the base, 28 inches wide at the top, 8 inches high, and spaced 5 ft apart on centers. Finished beds were fumigated with methyl bromide plus chloropicrin (67:33 v/v) at

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a rate of 175 lb/acre to eliminate soilborne diseases, nematodes, and weeds in the soil. Simultaneously, planting beds were covered with 0.6-mil-thick silver on black mulch, and drip irrigation tubing (T-Tape Systems International, San Diego) was buried 1 inch deep on the bed center. 'Florida-47' tomato transplants were established 2 ft apart on single rows on the center of each bed. Irrigation was supplied via subsurface irrigation at an approximate rate of 8000 gal/acre per day, and the soil was maintained at field capacity. The water table was maintained between 18 and 24 inches deep and constantly monitored with observation wells located in the fields. Plant nutrients, other than N and S, were supplied under non-limiting conditions through drip irrigation following current local recommendations (Olson et al., 2006).

The four treatments were arranged in a randomized complete-block design with four replications. Experimental units were 30 ft long with a 10-ft-long non-treated buffer zone at the end of each plot. Newly mature leaves were collected from each plot at 12 weeks after transplanting (WAT) to determine foliar S concentration. Tomato fruits were harvested twice (10 and 12 WAT) and separated into marketable and non-marketable. Resulting data were analyzed with General Linear Model procedure to determine treatments effects ($P = 0.05$), and treatment means were separated with single degree-of-freedom orthogonal contrasts (SAS Institute, 2000).

Results and Discussion

There were no significant treatment by season interactions for all evaluated variables. Fertilizer treatments affected tomato foliar S concentration and marketable fruit weight. Plots treated with either rate of AN or non-treated had the lowest foliar S concentration, ranging between 0.55% and 0.53% (Table 1). However, plots treated with S-containing fertilizers caused significant foliar S concentration increases when compared with the non-treated control and AN-treated plots. Average S concentration was about 0.74%, which was 40% higher than the concentration in non-treated control plots. There were no significant differences on foliar S concentration between AN + PS and ASN when compared within the same rates (Table 1). Therefore, adding S to the fertilization programs, regardless of S sources, increased tomato uptake of this nutrient.

Marketable fruit weight followed a similar pattern as that for S concentration in the tomato leaves (Table 1). There were no significant marketable yield differences in plots treated with either AN + PS or ASN, suggesting that different S sources caused no differential response on tomato production. Average marketable yield ranged between 27.5 and 28.2 ton/acre in the S-treated plots. In contrast, average yield in the AN-treated plots was 18.7 ton/acre, which was 44% and 42% less than the yields in the AN + PS and ASN-treated plots. The AN-treated plots had higher yields than the non-treated control, which can be attributed to the increased N rates.

It has been indicated that the sufficiency S range for tomato is between 0.3% and 0.8% on a dry weight basis (Olson et al., 2006), which appears to be excessively wide for specific S recommendations in tomato. In this case, there was a positive tomato yield response as concentration increased from about 0.53% in the non-treated control to 0.7% in the S-treated plots, demonstrating that application of S in tomato fertilization programs is essential to increase marketable yields. These results agree with those presented by Pavlista (2005), Rhoads and Olson (2000), and Susila (2001), who indicated that vegetable crops are responsive to S fertilization and that S sources did not cause differential responses on crop growth and development. Therefore, soil analysis should be performed in tomato fields before planting to determine appropriate S application rates. Because of the significant yield improvements with S fertilization, further research should closely reevaluate the S sufficiency rates for tomato production.

Table 1. Effects of S fertilization to tomato foliar S concentration and marketable yield.

Fertilizer sourcesz	N rate (lb/acre)	S rate (lb/acre)	Foliar S concn[z] (%)	Marketable fruit wt (ton/acre)
Control	---	---	0.53	12.4
AN	300	---	0.55	18.7
AN + PS	300	343	0.79	28.2
ASN	300	343	0.72	27.5
Single degree-of-freedom orthogonal contrasts			Significance	
Control vs. AN			NS	*
Control vs. AN + PS			*	*
Control vs. ASN			*	*
AN vs. AN + PS			*	*
AN vs. ASN			*	*
AN + PS vs. ASN			NS	NS

[z]AN = ammonium nitrate; PS = potassium sulfate; ASN = ammonium sulfate nitrate.

[NS, *]Nonsignificant or significant at $P < 0.05$, respectively.

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