Potassium Source and Rate for Polyethylene-mulched Tomatoes

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Abstract. Tomato (*Lycopersicon esculentum* Mill.) was grown with polyethylene mulch at five locations during a total of nine seasons to evaluate the effects of K source and K rate on fruit yield and leaf K concentration with drip and subsurface irrigation. K sources evaluated were KCl, K_2SO_4 , and KNO_3 , and K rates varied from 0 to 400 kg-ha⁻¹. Preplant soil K concentrations by Mehlich-1 extraction on the sandy soils and loamy sands used in the study varied from 12 mg·kg⁻¹ (very low) to 60 mg·kg⁻¹ (medium). In seven of the eight studies, K source did not significantly influence fruit yield or leaf K concentration. In the other study with subsurface irrigation at Bradenton in Spring 1992, marketable yields were significantly higher with KNO_3 than with KCl as the K source. Tomato fruit yield responded to the application of K in all studies. At Gainesville, Quincy, and Live Oak, with drip irrigation on soils testing low to medium in K, maximum yields were produced with 75 to 150 kg-ha⁻¹ K where the K was broadcast preplant. These rates were 25% to 30% higher than those predicted by soil test. At Bradenton and West Palm Beach on soils testing low to very low in K, where all or part of the K was applied in double bands on the bed shoulder with subsurface irrigation, yield responses were obtained to 225 to 300 kg-ha⁻¹ K. These rates exceeded the maximum recommended K rate of 150 kg-ha⁻¹. Tomato leaf tissue K concentrations increased linearly with increased rates of K application, but were not influenced by K source. These data suggest that the recommendation for K on soils testing low in K be increased from 150 to 210 kg-ha⁻¹ and that this increase should suffice for tomatoes grown with either drip or subsurface irrigation.

Tomato is the most valuable vegetable grown in Florida. During 1994–95, the crop was grown on 19,800 ha with an on-farm value of \$461 million (Geuder and Pugh, 1996). Most tomato production is on sandy soils that are irrigated with subsurface irrigation, but more recently some drip-irrigation has been used. These soils are typically low in N and K. Most tomato growers apply larger amounts of N and K fertilizer (225 to 670 kg-ha⁻¹ each) in an effort to reduce risks of nutrient deficiencies

associated with nutrient leaching, however, this use of excessive rates of N and K may reduce fruit yield and quality. In many early studies with polyethylene mulched tomato in Florida, both N and K rates were evaluated with varying results. With subsurface irrigation, yield responses were obtained to 242–278 kg-ha⁻¹ N–K in three studies and to 303–349 kg-ha⁻¹ N–K in one study (Everett, 1976), with no response reported in other studies to N–K rates from 102–112 to 306–336 kg-ha⁻¹ N–K (Persaud et al., 1976) and to 148N–30P–171K to 444N–90P–513K kg-ha⁻¹ (Csizinsky and Schuster, 1982). With drip and overhead irrigation, Persaud et al. (1976) obtained a linear increase in tomato yield from 102–112 to 306–336 kg-ha⁻¹ N–K.

Studies elsewhere in the United States and Canada regarding K requirements of tomato have also led to variable conclusions. On a sandy loam soil in Delaware that tested high in nonexchangeable K, a slight increase in to-

mato yield was obtained with an increase in K rate from 0 to 56 kg-ha⁻¹ (Martin and Liebhardt, 1994). In South Carolina on a loamy fine sand that tested very high in Mehlich-1 extractable K, tomato yield did not respond to K fertilization in three studies (Karlen et al., 1985). Processing tomato yields in Canada responded linearly to increased rates of K from 0 to 500 kg-ha⁻¹ on a silt loam soil that tested 65 mg·kg⁻¹ ammonium acetate extractable K. However, on sandy loam soils that tested 46 and 62 mg·kg⁻¹ extractable K, no response to applied K was obtained (Dick and Shattuck, 1987).

Little information was found on the effects of K source on tomato nutrition. Locascio et al. (1982) reported similar yields of drip irrigated tomato with NH_4NO_3 and KCl vs. KNO_3 and $Ca(NO_3)_2$ as N and K sources. However, in areas where soil soluble salts are high, K_2SO_4 and KNO_3 are commonly used for all or part of the K applied, as the salt indices of these K sources are lower than for KCl. A recent comparison of these K sources in bulk revealed costs of \$0.42, \$0.74, and \$0.88 per kg K from KCl, K_2SO_4 , and KNO_3 , respectively. The N cost for KNO_3 was calculated at \$0.77 per kg as N cost from NH_4NO_3 . These studies were conducted to evaluate the effects of K source and rate on tomato production on sandy soils, using varying fertilizer placement and irrigation practices typical of commercial practices, in five locations in Florida. The response to K rate was compared with the K rate recommended by Mehlich-1 extractable K soil test data.

Materials and Methods

Studies were conducted in Quincy on an Orangeburg fine sandy loam (fine-loamy, siliceous, thermic, Typic Paleudults) in Spring 1986, 1990, and 1991; in Gainesville on an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudults) in Spring 1986; in Live Oak on a Lakeland fine sand (thermic, coated Typic Quartzipsamments) in Spring 1990; in Bradenton on an Eau Gallie fine sand (sandy, siliceous, hyperthermic, Alfic Haplaquods) in Spring 1991, Spring 1992, and Fall 1992; and on a Myakka fine sand (sandy, siliceous, hyperthermic Aeric Haplaquods) in West Palm Beach (Winter 1990–91). ‘Sunny’ tomatoes were grown in all studies. Treatments in the 1986 studies at Quincy and Gainesville were arranged in a 2 × 2 factorial with two K sources (KCl and K_2SO_4) and two K rates (200 and 400 kg-ha⁻¹). In later studies, treatments were arranged in a 3 × 5 factorial with three K sources and five K rates. The K sources were KNO_3 , KCl, and K_2SO_4 and the K rates were 0, 75, 150, 225, and 300 kg-ha⁻¹ at Quincy, Live Oak, and Bradenton. A zero K treatment was included in all studies except at West Palm Beach where K rates were 75, 150, 225, 300, and 370 kg-ha⁻¹ and K was supplied as one-half each K_2SO_4 and KNO_3 . Treatments were arranged in a randomized complete-block design with four replications. Preplant soil K data and current Univ. of Florida recommendations for K based on Mehlich-1 extraction (Kidder et al., 1989) for each soil

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site are provided in Figs. 1 and 2, except for Gainesville, 1986 (soil tested med., 50 mg·kg⁻¹ K). Fertilizer was formulated to contain 225 kg·ha⁻¹ N from NH₄NO₃ (remainder for KNO₃ treatments), the respective K rate, and 45 kg·ha⁻¹ micronutrient mix. Fertilizer was applied broadcast in the bed with P as required by soil test at all locations except Bradenton and West Palm Beach. At Bradenton, P was applied broadcast in the bed and the N and K were applied in two bands on the bed shoulders. At Palm Beach, 75 kg·ha⁻¹ K was applied preplant broadcast and the remainder of the K was banded on the bed shoulders. All soils were fumigated with 67% methyl bromide–33% chloropicrin (392 kg·ha⁻¹) before application of black polyethylene mulch. Irrigation was supplied by subsurface at Bradenton and in Palm Beach, and by drip at Quincy, Live Oak, and Gainesville. Tomatoes were harvested and graded into of extra large (>73 mm in diameter), large (64 to 73 mm), and medium (58 to 64 mm) sizes of marketable fruit (USDA, 1976).

Results

In the 1986 studies at Gainesville and Quincy, marketable fruit yields were similar with KCl and K₂SO₄ as the K sources and with applications of 200 and 400 kg·ha⁻¹ K (data not shown). The preplant soil test K values were 60 and 50 mg·kg⁻¹, respectively, and the K recommendation was 95 kg·ha⁻¹ based on Mehlich-1 extractable K (Kidder et al., 1989).

In 1990 and 1991 at Quincy, soil test values at the study sites were 37 (medium) and 34 mg·kg⁻¹ K (low). Responses to K from soil test data were predicted for 95 and 120 kg·ha⁻¹ K on the two sites, respectively. In both years, marketable fruit yields were not affected by K source (data not shown), but yields were significantly increased with K fertilization (Fig. 1A). Yields in 1990 were increased from 52.9 t·ha⁻¹ with 0 K to 72.8 t·ha⁻¹ with K application. No significant difference in yield was obtained with K rates from 75 to 300 kg·ha⁻¹. In 1991, fruit yield was 18.5 t·ha⁻¹ with no K. Yields increased with each increase in K application from 75 to 150 kg·ha⁻¹. However, fruit yields were reduced with increases to 225 and to 300 kg·ha⁻¹ K. These yield responses to 95 to 150 kg·ha⁻¹ K were similar to those predicted by soil test.

Studies at Live Oak during 1990 were conducted on a soil testing medium in K (54 ppm) where the K recommendation was 95 kg·ha⁻¹ K. Fruit yields were similar with the K sources, KNO₃, KCl, and K₂SO₄ (data not shown). With no K application, the marketable fruit yield was 51.7 t·ha⁻¹ and was increased to an average of 59.6 t·ha⁻¹ with K application (Fig. 1B). Most of the yield increase occurred with the application of 150 kg·ha⁻¹ K. Thus, the recommendation of 95 kg·ha⁻¹ K appeared to be low.

Three studies were conducted at Bradenton on soils that tested low or very low in K. Responses to 120 to 150 kg·ha⁻¹ K were predicted. In two of the three studies (Spring 1991 and Fall 1992), K source had no effect on

Fig. 1. Main effects of K rate on tomato marketable yield. (A) Quincy during 1990 and 1991 on soil testing 37 (med.) and 34 (low) mg·kg⁻¹ K, respectively; recommendations were 95 and 120 kg·ha⁻¹, respectively. In 1990 and 1991, yield differences between no K and the mean K rate were significant (**); in 1991, K rate effect was quadratic (Q**). (B) Live Oak in 1990 on a soil testing 54 (med.) mg·kg⁻¹ K, recommendation for K was 95 kg·ha⁻¹. Yield difference between no K and the mean K rate was significant (**) and the K rate effect was Q**.

marketable yield (Fig. 2A). In the spring 1992 study, however, a significant response to K source was obtained. Marketable fruit yields were 19% higher with KNO₃ than KCl, but yield differences between other sources were not significant.

In all studies at Bradenton, total marketable yields were significantly increased by application of K (Fig. 2B). In 1991, marketable tomato yields increased linearly from 36.4 t·ha⁻¹ to 41.2 t·ha⁻¹ with an increase in K rate from 75 to 300 kg·ha⁻¹. In Spring and Fall 1992, the yield responses to K rate were also significant, but most of the response each season occurred with the application of 225 kg·ha⁻¹ K.

During Winter 1990–91, a K rate study with 50% KNO₃ and 50% K₂SO₄ as the K sources was conducted in West Palm Beach (Fig. 2C) on a soil testing 12 ppm K (very low) where a response to 150 kg·ha⁻¹ K was predicted. Marketable fruit yields were maximized with K between 225 and 300 kg·ha⁻¹, rates that were more than the 150 kg·ha⁻¹ K predicted for maximum yield.

Tomato leaf samples were taken throughout the season. Potassium source had no effect on leaf K concentrations at mid-season at any site (Table 1). Also, in seven of the eight studies where K source was evaluated, differences in yields were not significant. In the one study where yield with KNO₃ was significantly greater than with KCl, the yield difference could not be attributed to K nutrition because leaf-K concentrations were similar with all treatments. Fruit yields and leaf K concentrations with KNO₃ and KCl sources were previously reported to be similar (Locascio et al., 1982).

K rate significantly influenced leaf tissue K concentration at all sites where leaf samples were taken (Table 1). At Gainesville, Quincy, Live Oak, and Bradenton, increases in the rate of K application resulted in linear increases in leaf K concentration. At West Palm Beach, the increases in leaf K concentrations were quadratic. Tomato leaf tissue is very responsive to additions of K as previously reported (Hochmuth et al., 1991; Persaud et al., 1976).

In the nine studies where K rate was evalu-

Fig. 2. Main effects of K source and rate on tomato marketable yields. (A) Effects of K source at Bradenton were nonsignificant (NS) in Spring 1991 and Fall 1992, but in Spring 1992 yield was significantly (**) greater with KNO₃ than with KCl (KN vs. Cl**). (B) K rate at Bradenton in Spring 1991, Spring 1992, and Fall 1992 on soil testing 25 (low), 26 (low), and 15 (very low) mg·kg⁻¹ K, respectively; recommendations for K were 120, 120, and 150 kg·ha⁻¹, respectively. Yields were significantly higher (**) with K than with no K each year and rate effects were linear (L**) or quadratic (Q**). (C) K rate at West Palm Beach on a soil testing 12 (very low) mg·kg⁻¹ K; recommendation for K was 150 kg·ha⁻¹. K rate effect was Q**.

ated, responses were related to K placement and irrigation system used. With all broadcast preplant K fertilization and drip irrigation, maximum yields were produced with 75 to 150 kg·ha⁻¹ K, rates that were close to the amount of K predicted by soil test. With the application of K in double bands on the bed shoulder and with subsurface irrigation, maximum yields were obtained with 225 to 300 kg·ha⁻¹ K, more than the amount of K predicted by soil test.

These studies indicate that Univ. of Florida maximum K recommendation (Kidder et al., 1989) of 150 kg·ha⁻¹ K is 50% to 75% low for maximum tomato production with subsurface irrigation and band placement of the K on the bed shoulders, and that K placement has an effect on K efficiency. With band placement on the bed shoulders, predicted K requirements were much lower than were indicated by the response obtained. With shoulder-band placement, much of the K remained on the bed shoulder after the crop was harvested, therefore some of this fertilizer should be broadcast to increase use efficiency (Hochmuth et al., 1994). With broadcast-incorporated K placement with drip irrigation, predicted K needs were closer to the crop need as measured by the response obtained. An increase in the recommended rate of K fertilization should be considered on sandy soils testing very low in K from 150 kg·ha⁻¹ K to 210 kg·ha⁻¹, to 145 kg·ha⁻¹ with soil testing low, and to 95 kg·ha⁻¹ with soils that test medium in K.

In eight of the nine studies, source of K did not influence tomato yield or fruit size. This would indicate that factors other than horticultural crop response should be considered in choosing a K source such as cost and specific nutrient needs as N and S. With a common grower application of 670 kg·ha⁻¹ K from KNO₃, the cost for K alone would be about \$590 (plus the cost for N at \$0.77 per kg). In contrast, the cost of 225 kg·ha⁻¹ K from KCl would be \$95. Thus, the cost of this over K-fertilization would be \$495 per ha. If one-half of the acreage were over fertilized in this manner, the cost to the Florida tomato industry of the excess K fertilizer would be over \$4.9 million per year.

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Table 1. Main effect of K source and rate on tomato leaf K concentration at selected sites.

K source	Leaf K (g kg ⁻¹) ^a					
	Gainesville	Quincy	Live Oak	Bradenton		West Palm Beach
	1986	1990	1990	Spring 1992	Fall 1992	1990-91
KNO ₃	---	35	27	40	36	---
KCl	28	35	27	33	34	---
K ₂ SO ₄	29	32	29	33	32	---
Significance ^b	NS	NS	NS	NS	NS	---
			<i>K (kg·ha⁻¹)</i>			
0	---	18	21	21	13	---
75	---	27	23	30	28	17
150	---	33	27	32	30	23
200	26	---	---	---	---	---
225	---	37	29	39	39	32
300	---	40	31	39	40	33
375	---	---	---	---	---	34
400	31	---	---	---	---	---
Significance	**	L**	L**	L*	L**	L**, Q*
(0 vs. K)	---	**	**	*	**	---

^aDays after planting samples taken from Gainesville to West Palm Beach were 70, 68, 70, 67, 56, and 66 d, respectively.

^bNS, *, **Nonsignificant or significant at $P=0.05$ or 0.01 , respectively. K rate effects were linear (L) or quadratic (Q).

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