Tomato Yield and Fruit Size Did Not Respond to P Fertilization of a Sandy Soil Testing Very High in Mehlich-1 P

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Additional index words. soil testing, *Lycopersicon esculentum*, tissue testing

Abstract. Tomato (*Lycopersicon esculentum* Mill.) was grown in southeastern Florida on sandy soils that tested very high in Mehlich-1 P to evaluate the yield response to P fertilization. One location was used in 1995–96, another in 1996–97. Prefertilization soil samples contained 290 (location 1) and 63 (location 2) mg·kg⁻¹ Mehlich-1 P. Both soil test results were interpreted as very high in P, and P fertilizer was not recommended for the crop. Fertilizer treatments at both sites were 0, 25, 50, 100, 150, and 200 kg·ha⁻¹ P. Neither total marketable yield nor yield in any fruit size category was affected by P fertilization in either season. Amounts of cull (undersized or misshapened) fruits increased quadratically with P fertilization in the second season. Whole-leaf P concentrations increased linearly or quadratically with P application, depending on sample periods, and were always above sufficiency values. Although many tomato growers apply P fertilizer irrespective of soil test recommendations, our results showed that added P was not needed on soils testing very high in P. Furthermore, withholding P applications to soils with high P concentrations will minimize potential P pollution of surface water and groundwater.

Tomato is produced on ≈20,000 ha annually in Florida with a value of ≈\$0.5 billion (Witzig and Pugh, 1997). Tomato is one of the most expensive vegetable crops produced in Florida, with fertilizer accounting for ≈5% (\$800 per ha) of the preharvest costs (Smith and Taylor, 1995). Average fertilizer applications for tomato in Florida are reported to be 250 kg·ha⁻¹ N, 90 kg·ha⁻¹ P, and 360 kg·ha⁻¹ K (National Agricultural Statistics Service, 1990). Phosphorus is applied by growers even when soil tests indicate that no P fertilizer is needed.

The reasoning behind the regular P fertilization is the belief that extra fertilization insures against perceived fertilizer-related reductions in yield and quality, or that the soil P reserve must be maintained at a high level with continuous P additions. This philosophy is consistent with the “buildup and maintenance” approach to soil fertility (Fixen and Grove, 1990). Phosphorus leaches from soils with

moderate to low P fixing capacities (Rhue and Everett, 1987). Continued P applications to these soils could result, with time, in significant P losses to surface and groundwater. In addition, P contamination of surface water could result when erosion moves P-laden soil into bodies of water. The Univ. of Florida Extension Soil Testing Laboratory employs the Mehlich-1 (Mehlich, 1953) soil test extractant for sandy soils; this extractant has been calibrated for vegetable crop use (Hanlon and Hochmuth, 1992; Hochmuth and Hanlon, 1995).

Considerable field research and demonstration work has been done on P fertilization of vegetables in Florida. The most recent of these studies showed that crops growing on soils with high (>30 mg·kg⁻¹) Mehlich-1 extractable P did not respond to P fertilization (Hochmuth et al., 1993a; 1993b; Locascio et al., 1996; Rhoads et al., 1990; Rhue et al., 1981), supporting older observations that P had accumulated in vegetable lands because of continuous P fertilization (Hortensine, 1966; Westgate et al., 1958). Residual soil P can benefit crop production (Forbes and Westgate, 1962; Novais and Kamprath, 1978; Peck et al., 1987) as long as calibrated soil tests can predict crop response to P fertilization of a specific soil having a specific soil-test P index (Anderson, 1983; Hatzell and Blue, 1981; Kurtz, 1981; Sartain et al., 1979; Wolf and Baker, 1985). Phosphorus availability depends on several factors, including amount of P available in the soil (Fixen and Grove, 1990; Tisdale et al., 1985), soil temperature (Locascio

and Warren, 1960), and P fertilizer placement (Barber and Kovar, 1985; Kovar and Barber, 1987; Locascio et al., 1960). Even though tomato growers in Florida have high-P soils and are placing P in such a manner to allow for efficient P utilization, they still feel that larger-than-recommended amounts of P are required. This research was conducted to determine if this continual P fertilization of high-P soils was justified for tomato production.

Materials and Methods

Experiments were conducted in the winter tomato production seasons of 1995–96 (Expt. 1) and in 1996–97 (Expt. 2) on two commercial tomato farms in southeastern Florida. Expt. 1 was conducted in Boynton Beach, Fla., on an Oldsmar sand (Alfic, Arenic, Haplaquods, sandy, siliceous, hyperthermic) and Expt. 2 in Ft. Pierce, Fla., on a Malabar fine sand (Grossarenic Ochraqualls, siliceous, loamy, hyperthermic).

Fields used for both experiments were fallow for 4 to 6 months prior to each tomato crop, with weeds controlled by periodic disking. Soil preparation consisted of disking and laser-leveling. Prefertilization soil samples were taken of the upper 15 cm of soil and analyzed for P by the Mehlich-1 extraction method (Georgia Agricultural Experiment Station, 1983; Hanlon et al., 1994).

Before fertilization, the soil at Boynton Beach in Winter 1995–96 tested 290 mg·kg⁻¹ Mehlich-1 P, which was very high in P content. The soil pH was 7.2 in a 2 water : 1 soil mixture. Current Mehlich-1 soil test P calibration used by the Univ. of Florida places any soil test value >60 mg·kg⁻¹ in the very high category, and any soil test value between 30 and 60 mg·kg⁻¹ in the high category, and recommends no P fertilization for soils in either category (Hochmuth and Hanlon, 1995).

The soil at the second site (Expt. 2) tested 63 mg·kg⁻¹ Mehlich-1 P, which was a value near the breakpoint value (60 mg·kg⁻¹) between high and very high Mehlich-1 P categories. The soil pH was 7.0 in a 2 water : 1 soil mixture.

On 2 Nov. 1995 and 31 Jan. 1997, preplant fertilizer mixtures containing varying amounts of P were broadcast by hand in a 50-cm-wide band on the soil surface of the area to become the future raised, mulched planting bed. The fertilizer mixture in 1995 consisted of potassium magnesium sulfate, ammonium nitrate, magnesium sulfate, manganese sulfate, iron sulfate, zinc sulfate, and sodium borate. Rates of nutrients supplied in the preplant bed mix were (kg·ha⁻¹) 20 N, 36 K, 20 Mg, 4 Mn, 2 Zn, 2 Fe, and 1 B. The same materials were used for the fertilizer mixture in 1997 at rates (kg·ha⁻¹) of 40 N, 65 K, 60 Mg, 4 Mn, 2 Zn, 2 Fe, and 1 B.

The P rates used were 0, 25, 50, 100, 150, and 200 kg·ha⁻¹ P supplied from triple superphosphate. Fertilizer blends were applied to the soil and incorporated by bedding discs during the bed-making process. Beds were formed on 1.5-m centers and were 15 cm in height and 75 cm across the top surface. The

Received for publication 9 July 1998. Accepted for publication 18 Sept. 1998. Florida Agricultural Experiment Station Journal Series no. 6421. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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soil was fumigated with 400 kg-ha⁻¹ of a 98% methyl bromide : 2% trichloromethane (chloropicrin) mixture by injecting the fumigant into the soil during the bed-making process. Simultaneously, two grooves, 4 cm deep, were made in the surface of the bed, each 25 cm from the center of the bed, into which was placed a mixture of N and K fertilizer (determined by the commercial tomato grower) consisting of potassium nitrate, potassium sulfate, calcium nitrate, and ammonium nitrate to supply an additional 340 kg-ha⁻¹ N and 570 kg-ha⁻¹ K in 1995 and 285 kg-ha⁻¹ N and 390 kg-ha⁻¹ K in 1997. Finally, the beds were covered with black polyethylene mulch.

On 1 Dec. 1995 and 10 Feb. 1997, 'Solimar' (Asgrow Seed Co., Kalamazoo, Mich.) tomato transplants were planted through the mulch in a single row 56 cm apart in 1995 and 64 cm apart in 1997. Experimental plots were single rows 9.1 m in length in both experiments.

On 8 Dec. 1995 (35 d after P fertilizer application) and on 6 Mar. 1997 (34 d after P application), soil samples were taken from the beds in each plot to a depth of 15 cm. After final harvest in each experiment, soil samples were collected from the upper 15 cm of the soil in the bed and analyzed for P by Mehlich-1 extraction technique (Hanlon et al., 1994).

Except for fertilization practices, tomatoes were grown with cultural methods typical of those recommended for southeastern Florida

(Hochmuth, 1990; Hochmuth and Maynard, 1996). Plants were staked and tied two times during the first season and four times during the second season, using recommended staking and tying procedures. Irrigation was by subsurface irrigation from a raised water table maintained at 50 to 60 cm below the surface of the bed. This practice typically maintains the soil moisture potential at -8 to -10 kPa at a depth of 15 cm.

Plant diseases and insects were controlled by applications of standard recommended pesticides (Hochmuth and Maynard, 1996).

Whole-leaf tissue samples (sixth leaf from the branch tip) were collected for P analyses three times during each experiment, at flowering of the first and third fruit clusters, and at first harvest. Samples were collected on 12 Jan. 1995; 9 Feb. and 8 Mar. 1996; and on 24 Mar., 14 Apr., and 1 May 1997. Six leaves were taken for each experimental plot, dried in a forced-draft oven, and ground in a Wiley mill. A sample of the ground tissue was digested in sulfuric acid and hydrogen peroxide on a heating block and analyzed for P by plasma emission spectroscopy (Hanlon et al., 1994).

Tomatoes were harvested at the mature-green stage (Sherman, 1990) four times in the first experiment and three times in the second. Harvests were made on 14 and 26 Mar., and 10 and 23 Apr. 1996; and on 1, 9, and 19 May 1997. Fruits were graded into marketable and

cull (undersized and misshapened) fruits. Marketable fruits were further graded into size categories of extra large (>6.99 cm diam.), large (6.35–7.06 cm), and medium (5.72–6.43 cm) as specified in the Florida Tomato Marketing Order (Florida Tomato Commission, 1997a, 1997b).

Data were analyzed by analysis of variance. When treatment effects were significant, trends were modeled with regression analysis (SAS Institute, 1985).

Results and Discussion

Yield response, Expt. 1. Neither early (first harvest) nor total (four harvests) marketable yields were affected by P fertilization (Table 1). Early-season yields averaged 9.5 (extra large), 6.2 (large), and 2.8 (medium) t-ha⁻¹ and total-season yields averaged 17.0 (extra large), 19.4 (large), and 14.1 (medium) t-ha⁻¹. Total marketable yields were 18.5 (early) and 50.4 (season) t-ha⁻¹. These yields were very good by Florida standards as average yield was 34.1 t-ha⁻¹ in the 1995–96 tomato season (Witzig and Pugh, 1997). Total-season marketable fruit yield was 72% large- and extra-large-sized fruits, a proportion desired by commercial tomato growers. In another study on a nearby farm, tomato yield did not respond to P fertilization of a sandy soil testing 220 mg-kg⁻¹ Mehlich-1 P (Shuler and Hochmuth, 1995).

Amounts of cull fruits and average marketable fruit size were not affected by P fertilization (Table 1). Cull fruit production early in the season was small (≈18% of total early fruit production) vs. 27% for the entire season. These amounts of culls are not typical, but the 1995–96 season was uncharacteristically cold with several near-freeze events on 24 Dec. 1995; and 8–12 Jan., 4–6 Feb., and 18–19 Feb. 1996. These cool temperatures resulted in production of large amounts of undersized and misshapen fruits. Average fruit weight [185 g (early) and 153 g (season)], was not affected by P fertilization.

Whole-leaf P concentrations increased quadratically with an increase in P fertilization for the samples taken at first flower cluster and at third flower cluster stages, and linearly with P fertilization for samples taken at first harvest (Table 2). All whole-leaf P concentrations at all sampling periods were above published sufficiency ranges of 2 to 4 g-kg⁻¹ P (Hochmuth et al., 1991; Jones et al., 1991). The P concentrations early in the season were especially high, documenting that tomato plants

Table 1. Yield response of tomato to P fertilization of a sandy soil testing very high in Mehlich-1 extractable P, Boynton Beach, Fla., Winter 1995–96 (Expt. 1).

P rate ² (kg·ha ⁻¹)	Yield (t·ha ⁻¹) ^y					Avg mkt. fruit wt (g)
	Extra large	Large	Medium	Total mkt.	Cull	
<i>First harvest</i>						
0	8.9	6.7	2.9	18.5	4.8	185
25	9.2	6.4	2.8	18.4	3.5	185
50	10.0	5.1	2.6	17.7	4.7	190
100	10.0	6.3	2.5	18.8	4.1	185
150	9.4	7.2	2.7	19.3	3.3	185
200	9.2	5.7	3.1	18.0	4.1	180
Significance	NS	NS	NS	NS	NS	NS
<i>Season (four harvests)</i>						
0	15.8	20.8	14.0	50.6	18.8	150
25	16.7	18.8	13.5	49.0	19.9	155
50	18.3	17.9	14.2	50.4	17.7	155
100	16.5	18.5	14.0	49.0	18.3	155
150	17.5	20.6	14.5	52.6	18.1	155
200	17.1	19.5	14.3	50.9	18.7	150
Significance	NS	NS	NS	NS	NS	NS

²P rate calculated on basis of planting beds on 1.5-m centers but incorporated in the soil in the raised, mulched bed measuring 15 cm in height and 75 cm wide.

³Diameters: extra large (>6.99 cm); large (6.35–7.06 cm); and medium (5.72–6.43 cm).

NS=Nonsignificant.

Table 2. Response of tomato whole-leaf P concentrations to P fertilization of sandy soils testing very high in Mehlich-1 P in two experiments in Florida.

Expt.	Year	Location	Seasonal sampling period	P rate (kg-ha ⁻¹) ^z					Significance	
				0	25	50	100	150		200
-----Whole-leaf P concn (g·kg ⁻¹)-----										
1	1995–96	Boynton Beach	First cluster flowering	6.2	6.8	7.7	8.0	9.0	9.2	L**Q*
			Third cluster flowering	4.5	5.2	5.5	6.7	7.5	7.4	L**Q*
			First harvest	3.2	3.0	3.5	4.0	4.3	4.8	L**
2	1996–97	Ft. Pierce	First cluster flowering	6.3	6.8	7.2	7.3	7.3	7.0	L*Q**
			Third cluster flowering	5.2	5.3	5.8	6.0	6.7	6.8	L**
			First harvest	3.8	3.8	4.3	4.5	5.5	5.3	L**

²P rate calculated on basis of planting beds on 1.5-m centers but incorporated in the soil in the raised, mulched bed measuring 15 cm in height and 75 cm wide.

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively. Regression equations contained significant linear (L) or quadratic (Q) terms.

growing on this soil, very high in Mehlich-1 P, had ample P available to them without fertilization.

Yield response, Expt. 2. Marketable yields were not affected by P fertilization at this site in the 1996–97 winter season (Table 3). Yields were higher than in Expt. 1, possibly due partly to the new site on which few tomato crops had previously been grown, but also partly to a much more favorable growing season with no cold periods. Early fruit yields averaged 37.2 (extra large), 10.5 (large), and 0.2 (medium) t·ha⁻¹. Total marketable early yield averaged 47.9 t·ha⁻¹. For the season, the average yields were 55.4 (extra large), 23.0 (large), and 12.1 (medium) t·ha⁻¹. Average total marketable season yield was 90.4 t·ha⁻¹. Large and extra large fruits made up 99% of the early marketable fruit production and 87% of the total-season fruit production.

Amounts of cull fruits increased quadratically with P fertilization (Table 3). Although affected by P fertilization, amounts of cull fruits were very low overall, averaging 4% of early fruit and 3% of total-season fruit production. Average fruit weight was not affected by P fertilization, averaging 210 g per fruit in the first harvest and 193 g per fruit for the season (Table 3).

Whole-leaf P concentrations at first flower cluster increased quadratically with P applied (Table 2), and concentrations at third cluster and at first harvest increased linearly. All

whole-leaf P concentrations with all P treatments at all sampling periods were within or above published sufficiency ranges of 2 to 4 g·kg⁻¹ P for tomato (Hochmuth et al., 1991; Jones et al., 1991) and similar to the P concentration values of tomato leaves at the Boynton Beach site.

These results indicate that tomatoes growing on two soils testing very high in Mehlich-1 P had adequate P available to them. The results were the same even though one soil tested near the breakpoint on the Univ. of Florida calibration curve for high–very high soils.

Soil P content. Mehlich-1 tests conducted on soil samples from each site, taken shortly after fertilization and at the end of the season, showed that the P soil test index increased in response to added P fertilizer, especially at Ft. Pierce (Table 4). Although extractable P declined during the season in the soil fertilized with P, the values after harvest were still very high and were higher than the beginning (unfertilized) P soil test values, illustrating P accumulation in these soils, especially where P was applied at 100 kg·ha⁻¹ or more, rates similar to the typical commercial P rate of 90 kg·ha⁻¹. With no P fertilizer added, the early and postseason soil test values at both sites were similar (same soil-test interpretation) to those of the unfertilized soil at the beginning of the season. The small differences in values, e.g., 63 mg·kg⁻¹ at prefertilization and 88

mg·kg⁻¹ at early sampling at Ft. Pierce, were probably due to sampling variability. The prefertilization samples were random samples from the experimental area and the early samples were taken from the specific plots with the zero-P treatment. This result is the same as that obtained by Selles et al. (1995) where, in multi-year cropping systems receiving no P, the Olsen P soil test index remained constant. The Mehlich-1 P index of unfertilized soil also remained unchanged after tomato cropping in another study with tomato in Florida (Shuler and Hochmuth, 1995).

In work with corn and soybean in Minnesota, Randall et al. (1997) measured the decline in soil-test P concentrations over a 20-year cropping period, and concluded that growers with soils with high soil-test P need not apply P. With grain crops, most P is removed from the soil in the harvested grain, assuming erosion is nil and that P does not leach in most agricultural soils (Barrow, 1980). Rhue and Everett (1987) showed that P could leach on acidic, coarse sandy soils, but liming acidic soils minimized P losses. On the level, heavily limed sandy soils used in these tomato studies, the main avenue for P loss would be the harvested fruits, an amount reported to be ≈50 kg·ha⁻¹ (McVicker and Walker, 1978). Potential losses of P due to leaching from this coarse, sandy soil were not measured and this aspect should be addressed in further research.

In summary, tomato yields and fruit size did not respond to P fertilization of high- and very high-P soils on two commercial tomato farms in southeastern Florida. Whole-leaf tissue P concentrations were always more than adequate, showing that plants growing in the unfertilized soil had access to adequate P. Soil test results showed that P accumulated in these soils during the season and that tomato growth in the unfertilized soils did not affect the soil's P status. These results clearly show that routine P applications to soils that test very high in P are not warranted. Adhering to soil test predictions for P fertilization would improve tomato production profitability and minimize chances for P contamination of the environment by leaching to groundwater or erosion transport with soil to surface water bodies.

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Table 3. Response of tomato to P fertilization of a sandy soil testing very high in Mehlich-1 extractable P, Ft. Pierce, Fla., Winter 1996–97 (Expt. 2).

P rate ^z (kg·ha ⁻¹)	Yield (t·ha ⁻¹) ^y					Avg mkt. fruit wt (g)
	Extra large	Large	Medium	Total mkt.	Cull	
<i>First harvest</i>						
0	37.1	9.2	0.0	46.3	0.8	210
25	38.6	10.9	0.2	49.7	0.7	205
50	36.4	9.3	0.1	45.8	1.6	210
100	39.8	12.0	0.3	52.1	2.6	215
150	35.6	11.1	0.4	47.1	2.5	210
200	35.5	10.7	0.1	46.3	2.6	210
Significance	NS	NS	NS	NS	L ^{**} , Q [*]	NS
<i>Season (three harvests)</i>						
0	55.5	20.6	13.2	89.3	1.2	190
25	55.1	23.6	13.0	91.7	1.3	190
50	55.6	21.8	11.6	89.0	2.2	195
100	57.0	24.4	12.5	93.9	3.2	195
150	52.6	24.1	11.1	87.8	3.1	195
200	56.4	23.2	11.3	90.9	3.3	190
Significance	NS	NS	NS	NS	L ^{**} , Q [*]	NS

^zP rate calculated on basis of planting beds on 1.5-m centers but incorporated in the soil in the raised, mulched bed measuring 15 cm in height × 75 cm wide.

^yDiameter: extra large (>6.99 cm), large (6.35–7.06 cm), and medium (5.72–6.43 cm).

ns, * Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively. Regression equations contained significant linear (L) or quadratic (Q) terms.

Table 4. Response to P fertilization of Mehlich-1 extractable soil P concentrations measured twice in each of two tomato experiments in Florida.

Expt.	Year	Location	Sampling time ^y	P rate (kg·ha ⁻¹) ^z						Significance
				0	25	50	100	150	200	
				-----Extractable P (mg·kg ⁻¹)-----						
1	1995–96	Boynton Beach	Early	276	340	300	300	400	360	NS
			Late	230	260	270	300	390	430	L**
2	1996–97	Ft. Pierce	Early	88	104	102	135	150	150	L**
			Late	73	80	91	104	140	123	L**

^zP rate calculated on basis of planting beds on 1.5-m centers but incorporated in the soil in the raised, mulched bed measuring 15 cm in height and 75 cm wide.

^yEarly = 2 weeks after planting; late = after last harvest.

ns, ** Nonsignificant or significant at $P \leq 0.01$, respectively. Regression models contained significant linear (L) terms.

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