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NITROGEN REQUIREMENTS OF DRIP-IRRIGATED TOMATO

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Abstract. **Tomato (*Lycopersicon esculentum* Mill.) was grown with polyethylene mulch and drip irrigation on a Millhopper fine sandy soil testing high in P to evaluate the effect of N and P rates on plant growth and yield of fruit. Nitrogen was applied at rates of 0, 135, 202, 269, and 336 kg·ha[1] and P at 0 and 78 kg·ha[1]. The N and K (202 kg·ha[1]) were applied 40% preplant broadcast in the bed with the remaining 60% applied in 10 weekly drip applied applications and P was applied preplant. Irrigation was scheduled with tensiometers when the soil water tension reached 10 kPa. 'Agriset 761' plant growth, leaf N concentration, and marketable fruit yield were increased with the application of N and increased with an increase in N rate. The largest increase in yield occurred between the application of 0 to 135 kg·ha[1] N. Yields of extra-large, large, and medium fruits increased with each increase in N to about 269 kg·ha[1]. Total marketable yields with the above N rates from 0 to 336 kg N·ha[1] in t·ha^{-1} were 13.2, 51.3, 56.0,62.2, and 63.6, respectively. P fertilization rate had no effect on fruit yield.**

Florida continues to lead all other states in the adoption of drip irrigation for vegetables (Hochmuth et al., 1993; and Smajstrla et al., 1995). Tomato is the vegetable most widely grown with drip irrigation, and its use results in large water savings compared to the use of sprinkler and subsurface (seep) irrigation systems (Locascio and Myers, 1974). Currently, about 6,000 ha (Smajstrla et al., 1995) of the 19,800 ha tomato crop (Geuder and Pugh, 1996) are grown with drip-irrigation.

Extensive studies have been conducted mostly with seep irrigation to determine the fertilizer requirements of polyethylene mulched tomatoes. Everett (1976) found that maximum tomato production was obtained with 242-278 kg·ha^{-1} N-K in three of four spring studies. Persaud et al. (1976) reported that tomato yields on a Myakka fine sand were similar with N-K rates from 102-112 to 306-336 kg·ha^{-1}. Csizinsky (1980) reported that tomato yields were not influenced by an increase in N-P-K rates from 290-55-282 to 445-55-426 kg·ha^{-1}. In a later study (Csizinsky and Schuster, 1982), tomato yields and fruit size were not influenced by three-fold increases in N-P-K rates of 148-30-171 kg·ha^{-1}. These and other studies lead to the University of Florida Institute of Food and Agricultural Sciences (IFAS) tomato N-P-K recommendation of 180-78-150 kg·ha^{-1} (Hochmuth et al., 1988). The P-K rate recommendations are based on interpretation of soil test values from Mehlich-1 extractions. Hochmuth et al. (1989) found that tomato yields with subsurface irrigation were similar with N rates from 180 to 450 kg·ha^{-1} with the fertilizer placed in bands on the bed shoulders.

With drip-irrigation and overhead irrigation, Persaud et al. (1976) found that tomato yields increased linearly with an increase in N-K rates from a 102-118 kg·ha^{-1} to 306-336 kg·ha^{-1} where all of the fertilizer was applied preplant. Since soluble elements move with the wetting front (Bar-Yosef, 1977), highest tomato yields with drip irrigation on sandy soils are obtained with part of the N-K applied preplant and part with fertigation (Locascio and Myers, 1974; Dangler and Locascio, 1990; and Locascio et al., 1989). On an Orangeburg fine sandy loam soil, Rhoads et al. (1988) and Locascio et al. (1989) found that yields were not influenced by the time of N-K application. Locascio et al. (1996) also showed that on a sandy soil, tomato yields were lowest with 100% N-K applied preplant, intermediate with 100% applied by fertigation, and highest with 40% applied preplant with 60% applied by fertigation. No N-rate study was found where part of the N was applied by fertigation. In extensive K-rate studies (Locascio et al., 1994), it was found that K response was different with irrigation method and that IFAS recommended K-rates were lower than the rate required for maximum tomato production. These data, and others led to a revision in the N-P-K recommendations to 196-73-210 kg·ha^{-1} (Hochmuth and Hanlon, 1995).

Studies reported here were conducted to evaluate the response of tomato to N rate with drip irrigation where part of the N was applied preplant and part fertigated. To further evaluate fertilizer requirements of tomato, N rates were applied on a soil testing high in P, with and without additional P.

Materials and Methods

Tomato was grown on a Millhopper fine sandy soil at the Horticultural Unit near Gainesville during the spring of 1996. Treatments were factorial combinations of five N rates: 0, 135, 202, 269, and 336 kg·ha^{-1} N, and 2 P rates: 0 and 78 kg·ha^{-1} P. Before bed preparation, the soil pH was 6.3 and the soil tested 92 mg·kg^{-1} P, 31 mg·kg^{-1} K, 46 mg·kg^{-1} Mg, and 436 mg·kg^{-1} Ca (Mehlich-1 extraction). Beds were formed on 1.83-m centers with 0.6-m bed tops. Treatments were arranged in a randomized block design with treatments replicated four times on plots 11.0 m long. Forty percent of the N at the above rates from ammonium nitrate, P from triple superphosphate at the above rates, 80 kg·ha^{-1} K from potassium chloride (40% of the total 200 kg·ha^{-1} K rate) and 34 kg·ha^{-1} S from $MgSO_4$ were applied broadcast on the bed surface and rototilled into the soil 15 cm deep. Methyl bromide-chloropicrin (98-2%) was injected with two chisels per bed at 450 kg·ha^{-1} and 0.038 mm thick black polyethylene mulch was applied. Double-wall drip tubing (Chapin Twinwall, Watertown, NY) with emitters spaced 0.3 m apart with a flow rate of 62 ml·m^{-1}·min^{-1} was placed 10 cm from the bed center under the mulch for water and fertilizer application. 'AgriSet 761' tomato seedlings were transplanted 0.5 m apart on the bed on 14 Mar. 1996. Overhead irrigation (2.0 cm) was applied to the entire experimental

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area on 22 Mar. 1996 for freeze control. The remaining 60% of the N and K were applied in 10 equal weekly applications from the above sources with the drip irrigation system beginning on 3 Apr. 1996. Water was applied at 0.5 pan when the soil water tension reached 10 kPa as measured by tensiometers placed in the bed center at 15 cm depth in two plots. Tomatoes were pruned by the removal of the lowest two lateral branches, staked, and tied beginning two weeks after transplanting. Insecticides and fungicides were applied as needed.

Whole plant samples from each plot were taken on 17 Apr., 2 May, and 17 May 1996 for dry weight determination, and mineral element analysis. Recently matured whole leaves were also sampled on the above dates for mineral element analysis. Soil samples were taken from the bed center to a depth of 15 cm on the above dates and on 17 June 1996 and analyzed in the IFAS Soil Testing Laboratory. Fruit at the mature green or riper stages were harvested on 10 and 20 June 1996 and graded into extra-large, large, and medium size categories by U.S. grade standards. Data were analyzed by an analysis of variance and mean separation was by orthogonal comparisons.

Results and Discussion

Early, late, and total marketable yields of tomato fruit were significantly influenced by N rate (Table 1). The early yield of extra-large fruit was only 2.5 t·ha^{-1} with 0 N and was increased to 12.9 t·ha^{-1} with the application of 135 kg·ha^{-1} and yields increased to 14.8 t·ha^{-1} with the N application of 269 kg·ha^{-1}. Early total marketable yield was also highest with the application of 269 kg·ha^{-1} N. The late marketable yields were highest with the application of 335 kg·ha^{-1} N. The total marketable yield of extra-large fruit was only 3.2 t·ha^{-1} with the application of 0 N but was 20.7 t·ha^{-1} with the application of 135 kg·ha^{-1} N. A further increase in N to 336 kg·ha^{-1} resulted in an increase in yield to 26.2 t·ha^{-1}. The highest total marketable yield was also produced with the application of 336 kg·ha^{-1} N. However, the marketable yield with 269 kg·ha^{-1} N of 62.1 t·ha^{-1} was only 1.5 t·ha^{-1} lower than with the highest N rate.

Marketable fruit of tomato was not influenced by the application of P fertilizer. Early total marketable fruit yields were 20.3 t·ha^{-1} with the application of no P and 22.7 t·ha^{-1} with the application of 78 kg·ha^{-1} P (data not shown). Total marketable yields were 49.9 t·ha^{-1} and 48.7 t·ha^{-1} with the two P rates, respectively. Differences among size categorize in response to P rate were also not significant.

Tomato plant growth was influenced significantly by N rate at all sampling dates (Table 2). By 17 Apr., approximately four weeks after transplanting, plants were significantly larger with an increase in the rate of N applied to 336 kg·ha^{-1}. At the second and third samplings, plants were also largest with the highest N rate, but, the response to N rate was not linear. Most of the increased growth in response to N rate occurred with an increase in N application from 0 to 135 kg·ha^{-1} where the plant size was doubled at the second and third samplings. A further increase in N rate resulted in an additional 10% increase in plant size. The whole plant N concentration also responded rapidly to an increase in N rate. At the first sampling, N concentrations were increased linearly from 42 to 51 g·kg^{-1} with an increase in N rate from 0 to 336 kg·ha^{-1}. At the later two samplings, little increase in N concentration occurred with an increase in N rate higher than 135 to 202 kg·ha^{-1}. Whole leaf N concentrations followed a similar pattern as the whole plant in response to increased N rate except that N concentrations tended to be slightly higher in the recently matured whole leaf samples (Tables 2 and 3) than in whole plants. Leaf tissue Zn and Fe concentrations were significantly higher with application of N than with O N at all samplings except Zn concentration was not affected at the 17 Apr. sampling (Table 3).

Early plant growth was not influenced by P fertilization (Table 2), but plants sampled on 17 May were significantly larger with 78 kg·ha^{-1} P (120.5 g/plant) than with 0 P (106.7

Table 1. Main effects of N rate on tomato early, late, and total marketable yield, 1996.

N (kg·ha^{-1})	Marketable yield (t·ha^{-1}) Ex-large	Large	Medium	Total
		Early		
0	2.5	1.5	3.7	7.7
135	12.9	5.8	4.8	23.5
202	14.1	7.2	4.2	25.5
269	14.8	7.4	4.2	26.4
336	13.6	6.9	3.7	24.2
	Q**'	Q**	NS	Q**
		Late		
0	0.7	0.7	4.2	5.6
135	7.8	5.4	14.7	27.9
202	9.5	5.7	15.2	30.4
269	10.1	7.4	18.2	35.7
336	12.6	7.2	19.6	39.4
	L**	Q**	Q*	Q**
		Total		
0	3.2	2.2	7.9	13.3
135	20.7	11.2	19.5	51.4
202	23.6	12.9	19.4	55.9
269	24.9	14.8	22.4	62.1
336	26.2	14.1	23.3	63.6
	Q**	Q**	Q**	Q**

'Treatment effects were nonsignificant (NS) or significant at the 1% level (**). N rate effects were linear (L) or quadratic (Q).

Table 2. Main effect of N and P rate on tomato whole plant weight and on N and P content, 1996.

	Whole plant (dry weight) g/plant 17 Apr	2 May	17 May	N (g·kg^{-1}) 17 Apr	2 May	17 May
N (kg·ha^{-1})						
0	3.8	27.5	49.5	42	26	11
135	6.3	50.0	127.2	45	34	18
202	6.0	52.6	128.5	47	35	22
269	6.0	51.0	125.0	48	37	24
336	7.0	55.6	138.5	51	35	26
	L**'	Q**	C**	L**	Q**	Q**
P (kg·ha^{-1})				P (g·kg^{-1})		
0	5.2	47.5	106.7	6.1	6.1	3.6
78	6.4	47.1	120.5	6.2	5.8	4.2
	NS	NS	**	NS	NS	**

'Treatment effects were nonsignificant (NS) or significant at the 1% level (**). N rate effects were linear (L), quadratic (Q), or cubic (C).

Table 3. Main effects of N rate of leaf tissue N, Zn, and Fe concentrations at three sample times, 1996.

	Leaf concentration (dry wt)								
	N ($g \cdot kg^{-1}$)			Zn ($mg \cdot kg^{-1}$)			Fe ($mg \cdot kg^{-1}$)		
N ($kg \cdot ha^{-1}$)	17 Apr	2 May	17 May	17 Apr	2 May	17 May	17 Apr	2 May	17 May
0	45	24	15	105	35	17	104	73	67
135	51	33	23	110	51	24	110	92	83
202	51	39	27	100	53	24	104	94	91
269	51	40	27	106	58	25	110	94	91
336	51	40	32	124	53	30	120	92	101
	Q**z	Q**	Q	NS	L**	L**	NS	Q*	L**

zTreatment effects were nonsignificant (NS) or significant at the 1% level (**). N rate effects were linear (L) or quadratic (Q).

Table 4. Main effect of N rate on soil pH, NH_4-N and NO_3-N, 1996.

	Soil analysis data											
	pH				NH_4-N ($mg \cdot kg^{-1}$)				NO_3-N ($mg \cdot kg^{-1}$)			
N ($kg \cdot ha^{-1}$)	17 Apr	2 May	17 May	17 June	17 Apr	2 May	17 May	17 June	17 Apr	2 May	17 May	17 June
0	6.9	7.1	7.0	7.6	90	61	52	28	43	27	67	37
135	6.6	6.6	6.6	7.1	124	87	52	28	183	107	98	66
202	6.6	6.5	6.4	7.0	157	99	59	38	296	161	110	38
269	6.6	6.4	6.3	6.6	200	137	72	33	337	257	213	30
336	6.5	6.3	6.3	6.8	188	152	95	28	678	347	292	57
	L**z	Q**	L**	L**	L**	L**	Q**	NS	L**	L**	Q*	C*

zTreatment effects were nonsignificant (NS) or significant at the 1% level (**). N rate effects were linear (L) or quadratic (Q).

g/plant). Whole plant P concentrations were also affected only at the third sampling where concentrations were higher (4.2 $g \cdot kg^{-1}$)with the higher P rate than with 0 P (3.6 $g \cdot kg^{-1}$). P fertilization had little effect on leaf tissue Zn or Fe concentrations (data not shown).

Soil pH values were significantly lower with N application than with 0 N at all four samplings (Table 4). The increase in soil acidity (pH) ranged from 0.4 units at the first sampling to 0.8 units at the end of the season. This increase in acidity was in response to the nitrification of the NH_4-N. In contrast, the soil pH in tomato plots not receiving N increased from 6.9 at the 17 Apr. sampling to 7.6 at the 17 June sampling. This increase in increase in alkalinity was probably due to an accumulation of $CaCO_3$ from the irrigation water. With the application of 0 N, soil Ca increased from 546 $mg \cdot kg^{-1}$ at the 17 Apr. sampling to 724 $mg \cdot kg^{-1}$ at the 17 June sampling.

Soil NH_4-N and NO_3-N concentrations responded with increased rate of N applications at the first three samplings. At the 17 Apr. sampling, NH_4-N concentrations doubled from 9.0 $mg \cdot kg^{-1}$ with 0 N applied to 20.0 $mg \cdot kg^{-1}$ with the application of 269 $kg \cdot ha^{-1}$ N. Soil NO_3-N concentrations were increased over 15 times from 4.3 $mg \cdot kg^{-1}$ with O N to 67.8 $mg \cdot kg^{-1}$ with the application of 336 $kg \cdot ha^{-1}$ N. As the season progressed to the 17 June sampling, the responses to N rate were similar to that at the 17 Apr. sampling except that concentrations of NH_4-N and NO_3-N were about 50% lower. At the 17 June sampling with the application of 0 N, concentrations of NH_4-N and NO_3-N were only 28 $g \cdot kg^{-1}$ and 37 $g \cdot kg^{-1}$, respectively. The soil concentration of NH_4-N was not affected by N rate and the NO_3-N concentration was only 57 $g \cdot kg^{-1}$ with the application of 336 $kg \cdot ha^{-1}$ N. These data reflect the rapid nitrification of applied NH_4-N with the last fertigation of N and K on 5 June. The low NO_3-N concentrations at the 17 June sampling indicated plant absorption and/or leaching during this period of fruit harvest and no fertigation.

Table 5. Main effect of P rate on soil pH and P concentration, 1996.

	Soil analysis data			
P ($kg \cdot ha^{-1}$)	17 Apr	2 May	17 May	17 June
		Water pH		
0	6.7	6.7	6.6	7.1
78	6.6	6.5	6.4	7.0
	NSz	**	*	NS
		Mehlich-1 P ($mg \cdot kg^{-1}$)		
0	101	98	93	94
78	126	131	108	108
	**	**	**	**

zEffects were nonsignificant (NS) or significant at the 5% level (*) or 1% level (**).

The main effects of P rate on soil pH and P concentration are shown in Table 5. The soil pH values at the 2 May and 17 May samplings were 0.2 units lower with the application of 78 $kg \cdot ha^{-1}$ P than with 0 P. Earlier and later in the season, pH was not affected by P rate. Soil P concentrations were higher at each sampling with the application of P.

Data from this study indicated that tomato plant N concentrations increase with increased rates of N application to 336 $kg \cdot ha^{-1}$ early in the season and total marketable fruit yield increased to 269 $kg \cdot ha^{-1}$. In previous work with drip irrigated tomato, Persaud et al. (1976) reported yield increased to 306-336 $kg \cdot ha^{-1}$ N-K when all fertilizer was applied preplant.

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PLANT PETIOLE SAP TESTING FOR NITROGEN AND POTASSIUM IN SWEET CORN GROWN ON MINERAL SOIL

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Abstract. **A spring fertilizer trial for sweet corn (*Zea mays* var. rugosa Bonaf.) was conducted on a Myakka fine sand. A soil test (Mehlich-1) taken before fertilizer was applied indicated P to be very high (120+ ppm) and K to be low (26 ppm). Four rates of N (0, 75, 150, and 225 lb/acre) and four rates of K (0, 50, 100, and 150 lb/acre) were applied in all combinations with one-third broadcast and the remainder in two side dress applications. Plant N and K were measured by sampling the most recently mature leaf petioles 27, 40, and 49 days after planting with Cardy ion specific meters (Spectrum Technologies, Inc., Plainfield, IL). Five to six petioles were necessary for sufficient sample size. Additional petioles were collected and analyzed by the University of Florida's Analytical Research Laboratory, Gainesville, to compare results with field sap tests. Harvesting for yield was 67 and 70 days after planting. Ear length, diameter, average weight, tip fill, and husk cover were not different for the 150 and 225 lb/acre of N. Marketable yield varied, but was generally higher when N rates were higher.**

The 1994-95 Florida sweet corn (*Zea mays* var. rugosa Bonaf.) crop was valued at $105.3 million (Geuder and Pugh, 1996). The average yield for the state was 312 42-lb crates per acre on 36,900 acres. About 70% was produced on organic soils in the Everglades and Zellwood regions. However, significant production occurs on sandy soils, and with the possible loss of the Zellwood organic soils (about 20% of the state's production), more production may be moved to the sandy soils.

Nitrogen (N) fertilization is necessary for growth and optimum sweet corn production, especially on sandy soils. Sweet

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