Fertilizer Placement Effects on Soil Nitrogen and Use by Drip-irrigated and Plastic-mulched Tomatoes

Wilton P. Cook

Coastal Research and Education Center, Clemson University, 2865 Savannah Highway, Charleston, SC 29414

Douglas C. Sanders

Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695-7609

Additional index words. *Lycopersicon esculentum*, fertilizer placement, nutrient uptake, drip irrigation, soil moisture

Abstract. The effects of fertilizer placement and soil moisture level on soil N movement, uptake, and use by tomato plants (*Lycopersicon esculentum* Mill) grown with drip irrigation and plastic mulch were evaluated at two locations on two types of sandy soils. Broadcast or band fertilizer placement had no effect on fruit size, fruit number, or total yield. Fruit size was increased at one location, and the incidence of blossom-end rot was decreased by increased frequency of irrigation. Nitrate-N distribution within the bed was not affected by initial N placement. In the soil with a rapid infiltration rate, NO₃-N levels in the center of the bed were always low, with highest concentration observed in the areas of the bed most distant from the drip tube. In the soil with the slower infiltration rate, NO₃-N concentrations were more uniform throughout the bed, with highest concentrations in the bed center. Increasing soil moisture levels (–20 kPa vs. –30 kPa) resulted in increased leaching and reduced NO₃-N concentration throughout the bed. Foliage N concentration was not affected by N placement, but decreased seasonally. Total N uptake by the above-ground portion of the plants was not affected by fertilizer placement or soil moisture level.

The use of drip irrigation, combined with plastic mulch, for tomatoes has raised new questions about fertilizer placement and use efficiency. Higher yields with broadcast, rather than band, placement of fertilizer have been reported (Locascio et al., 1981; Persaud et al., 1976); however, effects of placement methods on redistribution of N in soils and plant use of N have not been adequately addressed. Since plastic mulch should be laid when soil moisture is abundant (Cook et al., 1980), early season root exploration of the entire bed should occur (Knavel and Mohr, 1967). As the season progresses, the side of the bed away from the drip tube can become extremely hot and dry, creating conditions

unfavorable for root growth (Bar-Yosef, 1977; Bar-Yosef et al., 1980). If this occurs, fertilizer in that area may become unavailable for root exploration and nutrient uptake, resulting in inadequate nutrients for optimum growth. Concentrating the fertilizer close to the drip tube may result in excessive leaching (Bresler, 1975; Goldberg et al., 1971; Graetz et al., 1978).

This study was conducted to determine the effects of fertilizer placement and irrigation rate on leaching, uptake, and use of N by tomato plants.

Studies were conducted at Charleston, S. C., on a Yauhannah loamy fine sand (Aquic

Hapudult) with moderate infiltration rate (20 cm to subsoil) and at Clayton, N. C., on a Norfolk loamy sand (Typic Paleudult) with a rapid infiltration rate (≈40 cm to subsoil). The experimental design was a split plot with four replications. Main plots were two moisture levels maintained at –20 and –30 kPa at a depth of 15 cm. Sub-plot treatments were N applied banded or broadcast. Banded N was applied 8 cm deep and 18 cm on both sides of the bed center. A band containing 25%, 50%, or 75% of the N was placed on the side of the row with the drip irrigation tube, and the remainder of the fertilizer was placed on the opposite side of the row. The drip irrigation tube was placed 12 cm from the bed center and 4 cm deep. Switching tensiometers located in the center of the row at a depth of 15 cm controlled soil moisture levels above either –20 or –30 kPa. Broadcast treatments were uniformly spread on a preshaped bed and incorporated to a depth of 15 cm. All plots received 156 kg N, 54 kg P, and 213 kg K/ha. Calcium nitrate (15.5% N) was used as the N source for all treatments. Beds were fumigated with 98 methyl bromide :2 chloropicrin at 336 kg·ha^{–1} immediately before application of the 0.04-mm-thick black embossed plastic mulch. General production practices as outlined by Cook et al. (1980) were followed. ‘Sunny’ tomato seedlings were transplanted 3 Apr. 1985 at the Charleston location on a 0.6 × 1.8-m spacing and at Clayton on 29 Apr. at a spacing of 0.6 × 1.5 m. Bed tops were 0.9 m wide and 0.1 m high, and plots were 9 m in length. The outside row of each of the two adjacent plots was left unplanted so N movement could be monitored without interference from plant roots.

Soil samples were collected at depths of 0 to 15 cm and 15 to 30 cm. Samples were analyzed for NO₃-N with an ion-specific electrode (Kenney and Nelson, 1982). Soil samples were taken from the bed center and both sides of the bed, ≈24 cm from bed center and 6 cm outside the fertilizer bands. Samples were taken 2 weeks after planting and monthly until harvest was complete.

Nitrogen accumulation in the tomato plants was monitored by periodic foliage sampling

Table 1. Yield of various-sized mature-green tomato fruit as influenced by fertilizer placement and irrigation level at two locations.

Treatment	Marketable yield (t·ha ^{–1})					
	Charleston			Clayton		
	Small ^a and medium	Large	Total	Small and medium	Large	Total
Fertilizer placement ^b						
Broadcast	3.9	42.0	45.9	5.7	32.3	38.0
Banded 75–25	2.6	41.3	43.9	7.2	32.1	40.1
Banded 50–50	3.6	41.2	44.8	8.0	30.9	38.9
Banded 25–75	3.8	44.6	48.4	6.6	27.6	34.2
LSD _{0.05}	NS	NS	NS	2.3	NS	NS
Soil moisture level						
–30 kPa	4.9	39.7	44.6	6.1	31.1	37.2
–20 kPa	2.0	44.8	46.8	7.6	30.7	38.4
Significance _{0.05}	*	*	NS	NS	NS	NS

^aSmall is > 54 < 58 mm; medium is > 58 < 64 mm; large is > 64 mm.

^bFirst number indicates percent N in left side of bed and adjacent to drip tube. Second number indicates percent N in right side of bed and farthest from drip tube.

Received for publication 8 Mar. 1989. Paper no. 12066 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27695-7643. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products named, nor criticism of similar ones not mentioned. Partial funding for this research is from USDA Special Grant P.L. 89-106: Agricultural Adjustment in the Southeast Through Alternative Cropping Systems. Additional funding was from a grant by the South Carolina Tomato Growers' Assn. We gratefully acknowledge the support of the Asgrow Seed Co., Hendrix and Dail Co., and the staff of the Central Crops Research station and Coastal Research and Education Center. 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.

Table 2. Number of fruit with blossom-end rot as influenced by fertilizer placement and irrigation level at two locations.

Treatment	Blossom-end rot (no. fruit/ha, thousands)	
	Charleston	Clayton
Fertilizer placement ^a		
Broadcast	28.4	10.1
Banded 75—25	25.4	19.7
Banded 50—50	30.1	24.2
Banded 25—75	27.4	31.2
LSD _{0.05}	NS	15.2
Soil moisture level		
– 30 kPa	28.9	23.0
– 20 kPa	12.9	20.0
Significance _{0.05}	*	NS

^aFirst number indicates percent N in left side of bed and adjacent to drip tube. Second number indicates percent N in right side of bed and farthest from drip tube.

Table 3. The effect of fertilizer placement and sampling sequence on soil and foliage N concentrations.

Treatment	N concn			
	Foliage N (mg·g ⁻¹)		Soil NO ₃ -N (mg·kg ⁻¹)	
	Charleston	Clayton	Charleston	Clayton
Fertilizer placement ^a				
Broadcast	39.7	35.9	30.1	27.9
Banded 75—25	39.3	34.4	24.4	19.4
Banded 50—50	38.9	38.0	37.1	24.4
Banded 25—75	38.9	34.0	28.6	23.8
LSD _{0.05}	NS	NS	7.9	NS
Sampling period ^b				
15	45.9	42.5	43.2	31.5
45	40.8	34.2	24.4	18.9
75	31.0	30.4	16.9	16.3
Significance	L**	L**	L**	L*

^aFirst number indicates percent N in left side of bed and adjacent to drip tube. Second number indicates percent N in right side of bed and farthest from drip tube.

^bDays after planting for foliage analysis; days after fertilizer application for soil analysis.

***Linear (L) significant at $P = 0.05$ or 0.01 , respectively.

Table 4. Average seasonal soil NO₃-N levels as affected by sampling location and presence of vegetative growth, i.e., planted or nonplanted.

Factor	Soil NO ₃ -N (mg·kg ⁻¹) ^a			
	Charleston		Clayton	
	Planted	Nonplanted	Planted	Nonplanted
Depth				
0–15 cm				
Left side ^b	34.1 c	29.7 b	60.1 b	9.3 c
Center	67.0 a	25.7 b	20.6 c	23.0 b
Right side	50.0 b	73.4 a	141 a	78.0 a
15–30 cm				
Left side ^b	8.5 d	7.7 c	8.4 c	5.9 c
Center	11.2 d	6.7 c	7.8 c	6.4 c
Right side	9.5 d	11.5 c	16.9 c	10.9 c
Soil moisture level				
– 30 kPa	31.9	30.1	48.5	24.9
– 20 kPa	28.2	21.4	36.3	19.0
Significance _{0.05}	NS	*	NS	NS

^aMeans within columns and headings for depth separated by LSD at $P = 0.05$.

^bSample location in bed nearest drip tube.

of the first fully expanded leaves. Mature-green fruit was harvested twice at each location, graded, sized, examined for blossom-end rot (BER), and sampled for N concentration. Kjeldahl procedures (Tecator, 1985) were used for N analysis on all plant samples.

Root distribution in the bed was evaluated by cutting through each bed and examining a cross section of the bed 15 cm from the plant.

Analyses of variance were calculated and mean separation was by LSD.

Fertilizer placement had no effect on fruit size, marketable yield (Table 1), or fruit number (data not shown) at either location. Increasing soil moisture through more-frequent irrigation resulted in a decrease in the yield of smaller-sized fruit and an increase in the yield of the more valuable large-sized fruit at the Charleston location. Similar results were reported by Karlen and Robbins (1983) and Karlen et al. (1985). Irrigation rate had no effect on fruit size or yield at the Clayton location. At Charleston, the incidence of BER was not affected by fertilizer

placement, but was reduced more than 50% by increased irrigation (Table 2). A trend toward reduced incidence of BER was also observed at the higher irrigation rate at the Clayton location. BER incidence at both locations was higher than would normally be expected with drip irrigation. A 4-day breakdown of the irrigation system at Charleston and several recurring problems at Clayton presumably were responsible for the excessive BER. Broadcasting the fertilizer resulted in the lowest incidence of BER at Clayton. A proliferation of roots was observed (data not shown) in the vicinity of the fertilizer band, as reported earlier by Persaud (1977). Broadcasting the fertilizer resulted in a more diffuse root system at Clayton but not at Charleston (data not shown). Reduced salt injury with the broadcast fertilizer and the more diffuse root system probably resulted in increased Ca absorption and the subsequent reduction in BER (Table 2). When the fertilizer was banded, reducing the percentage of the fertilizer in the side of the bed nearest the drip irrigation tube resulted in an increased incidence of BER at Clayton. Dry soil and a lack of roots in the side of the bed away from the drip irrigation tube was observed during soil sampling at Clayton and may have contributed to inadequate Ca uptake.

Neither fertilizer placement nor irrigation rate had any effect on N content of the fruit at either location (data not shown). These treatments also had no effect on foliage N concentration. Foliage N concentration decreased as the season progressed (Table 3). Concentrations of N were always within acceptable levels (Tanaka et al., 1974). Foliage N concentration was slightly higher at the Charleston location at each sampling date, probably a reflection of higher residual soil N levels at Charleston. Neither fertilizer placement nor soil moisture level had any influence on total N uptake by the above-ground portion of the plant (data not shown). More-vigorous vine growth at Charleston resulted in greater N uptake at that location.

Soil NO₃-N levels in the bed varied with sample site and location (Table 4). At Charleston, in the 0- to 15-cm depth, the highest NO₃-N levels were found in the center of the bed. At Clayton, the center of the bed had the lowest NO₃-N concentration. The moderate infiltration rate of the soil at Charleston resulted in an observed wider moisture distribution pattern at the 15-cm depth than with the rapid infiltration rate of the soil at Clayton (32 cm vs. 18 cm after 4 hr of irrigation). The wide wetting pattern at Charleston resulted in uniform leaching throughout the bed. At Clayton, the narrow wetting pattern resulted in a greater volume of water moving through a limited amount of soil. Subsequently, extensive NO₃-N leaching occurred close to the drip irrigation tube, while NO₃-N accumulated in the opposite and drier side of the bed. Nitrate-N levels in the 15- to 30-cm depth were similar in both locations and generally much less than in the 0- to 15-cm depth. Nitrate-N leached from the 0- to 15-cm depth did not

accumulate in the 15- to 30-cm depth.

Seasonal decreases in $\text{NO}_3\text{-N}$ levels were similar at both locations (Table 3). The initial lower $\text{NO}_3\text{-N}$ levels at Clayton were due to slightly lower residual levels in the soil and increased leaching from preplant irrigation.

At the Clayton location, soil $\text{NO}_3\text{-N}$ levels were about twice as high in the beds with actively growing plants as in the nonplanted beds (Table 4). Greater soil moisture levels and increased leaching in the nonplanted beds more than offset the lack of N uptake by the plants. A much smaller difference was observed at the Charleston location, where leaching was slightly less severe due to greater lateral water movement. More-vigorous plant growth at the Charleston location also resulted in greater N uptake. Nitrate-N distribution within the bed was also affected by the presence of plants. The absence of water uptake in the nonplanted plots resulted in constant soil moisture levels near field capacity in those areas of the bed close to the drip tubing. Consequently, $\text{NO}_3\text{-N}$ levels in the center and left side of the bed tended to be lower and more uniformly distributed than in the planted plots, where moisture levels fluctuated.

Maintaining soil moisture levels at or above -20 kPa resulted in lower soil $\text{NO}_3\text{-N}$ levels than maintaining soil moisture at -30 kPa (Table 4). Increased leaching from the additional water at the -20 kPa irrigation level was probably responsible for most of the additional $\text{NO}_3\text{-N}$ losses, although plant uptake may have been a factor in the planted plots. The potential for reduced BER and increased yields at relatively high soil moisture levels (higher than -20 kPa) more than offsets any negative effects of increased $\text{NO}_3\text{-N}$ leaching.

Literature Cited

- Bar-Yosef, B. 1977. Trickle irrigation and fertilization of tomatoes in sand dunes: Water, N, and P distributions in the soil and uptake by plants. *Agron. J.* 69:486-491.
- Bar-Yosef, B., C. Stemmers, and B. Sagir. 1980. Growth of trickle-irrigated tomato as related to rooting volume and uptake of N and water. *Agron. J.* 72:815-822.
- Bresler, E. 1975. Two-dimensional transport of solutes during non-steady infiltration from a trickle source. *Proc. Soil Sci. Soc. Amer.* 39:604-613.
- Cook, W. P., R.P. Griffin, C.E. Drye, and P.J. Rathwell. 1980. Commercial tomato production in South Carolina. Clemson Univ. Coop. Ext. Bul. 625.
- Goldberg, D., B. Gornat, and Y. Bar. 1971. The distribution of roots, water and minerals as a result of trickle irrigation. *J. Amer. Soc. Hort. Sci.* 96:645-648.
- Graetz, D. A., J.G.A. Fiskell, S.J. Locascio, and B. Zur. 1978. Chloride and bromide movement with trickle irrigation of bell peppers. *Proc. Fla. State Hort. Soc.* 91:319-322.
- Karlen, D.L. and M.L. Robbins. 1983. Management practices for fresh-market tomato production in the Southeastern Coastal Plain. *HortScience* 18(5):732-734.
- Karlen, D. L., C.R. Camp, and M.L. Robbins. 1985. Fresh market tomato response to N and K fertilization and water management practices. *Commun. Soil Sci. Plant Anal.* 16(1):71-81.
- Kenney, D.R. and D.W. Nelson. 1982. Nitrogen inorganic forms, p. 643-698. In: A.L. Page, R.H. Miller, and D.R. Keeney (eds.). *Methods of soil analysis*. Part 2. 2nd ed. Amer. Soc. Agron., Madison, Wisc.
- Knave, D.E. and H.C. Mohr. 1967. Distribution of roots of four different vegetables under paper and polyethylene mulches. *Proc. Amer. Soc. Hort. Sci.* 91:589-597.
- Locascio, S. J., J.G.A. Fiskell, and F.G. Martin. 1981. Responses of bell peppers to nitrogen sources. *J. Amer. Soc. Hort. Sci.* 106:628-632.
- Persaud, N., S.J. Locascio, and C.M. Geraldson. 1976. Effect of rate and placement of nitrogen and potassium on yield of mulched tomato using different irrigation methods. *Proc. Fla. State Hort. Soc.* 89:135-138.
- Persaud, N., S.J. Locascio, and C.M. Geraldson. 1977. Influence of fertilizer rate and placement and irrigation method on plant nutrient status, soil soluble salts and root distribution of mulched tomatoes. *Soil & Crop Sci. Soc. Fla.* 35:121-125.
- Tanaka, A., K. Fujita, and K. Kikuchi. 1974. Nutrient-physiological studies on the tomato plant. I. Outline of growth and nutrient absorption. *Soil Sci. Plant Nutr.* 20:57-68.
- Tecator. 1985. Kjeltec System 1003 Distilling Unit. Tecator, Hoganas, Sweden.

HORTSCIENCE 25(7):769-771. 1990.

Isolation and Characterization of a Chemical from Tomato Apices that Stimulates Plant Growth

Yichun Wang, Violet Wert, Muraleedharan Nair, and Stanley Ries
Department of Horticulture, Michigan State University, East Lansing, MI 48824

Additional index words. plant growth regulator, shoot apex, plant hormone, *Chlamydomonas reinhardtii*, *Lycopersicon esculentum*

Abstract. A methanol: water extract of tomato (*Lycopersicon esculentum* Mill.) apices increased the growth of the alga *Chlamydomonas reinhardtii*. The active substance from the dried shoot apices was purified by C_{18} flash column and high performance liquid chromatography. The purified extract enhanced the growth of tomato, corn (*Zea mays* L.), and rice (*Oryza sativa* L.) seedlings at concentrations less than $1.0 \text{ mg-liter}^{-1}$. With *Chlamydomonas*, the purified extract increased cell division 111% at $0.1 \text{ mg-liter}^{-1}$ and chlorophyll content 23% at 10 mg-liter^{-1} in 18 hours. Nuclear magnetic resonance and mass spectroscopy indicated that the purified fraction was a mixture of compounds having sugar moieties. Analysis by thin layer chromatography showed that the fraction was ninhydrin positive and more polar than the known plant hormones studied.

Since cell division and elongation are important functions in shoot apices, they may be a source of unknown plant growth substances other than auxins, gibberellins, cytokinins, ethylene, and abscisic acid (Davies, 1987). This research was initiated to test the hypothesis that there are unknown chemicals in the shoot apex that stimulate plant growth. Since, with higher plant species, it is difficult to screen more than a few plant extracts at one time or to detect small differences because of the time required and the number of plants needed, the alga *Chlamydomonas reinhardtii* was used to screen the many chromatographic fractions obtained in the isolation procedure. In less than 24 hr, information could be obtained that would take at least 2 weeks with higher plants. Any compound that appeared interesting had to

be screened on higher plant species before proceeding to chemical identification and practical applications.

After evaluating extracts from several plant species, including wheat (*Triticum aestivum* L.), cabbage (*Brassica oleracea capitata* L.), carrot (*Daucus carota* L.), rice (*Oryza sativa* L.), and tomato (*Lycopersicon esculentum* Mill.), for stimulator activity, tomato was selected for further study because of the response of the alga and the ease of obtaining plant material.

Tomato shoot apices were obtained from 25-day-old greenhouse-grown 'Ohio 7870' tomato plants. These were grown in $30 \times 30\text{-cm}$ styrofoam flats under metal halide lights, with a photosynthetic photon flux of $425 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ measured at the top of the canopy. A 14-hr photoperiod was maintained with air at $\approx 28^\circ\text{C}$ day/ 22°C night. The plants were fertilized weekly with soluble 20N-20P-20K fertilizer (500 ml/flat) at a rate of 1.0 g-liter^{-1} water. The shoots were harvested and lyophilized at 5°C for 24 hr. After large numbers of shoots were collected, the apices (5-10 mm) were removed and stored frozen in glass containers before being ground

Received for publication 14 Nov. 1988. Michigan Agricultural Experiment Station Journal Article no. 12890. 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.