blooming has been an advantage. In addition, many of the breeding programs in northern states have been closed, so there are fewer new varieties developed with a higher chilling requirement or higher bud hardiness. Older varieties may be less competitive in terms of size, firmness, or attractiveness, so the newer lower-chill varieties have often been planted instead.

Those varieties cropped over several locales, such as 'LaPremiere' and 'Contender', are good candidates for growers to plant as insurance against similar losses. Some of these varieties are less competitive in normal or low-chill years, and a grower may want to plant other varieties as well in their season. The cropping ability of some breeding material suggests that crop tolerance to spring frosts may be improved further.

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Responses of Field-grown Tomatoes to Nitrogen Sources

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ADDITIONAL INDEX WORDS. fertilizer, nutrition, primary nutrients, fertigation

SUMMARY. Although the effect of various N fertilizers on tomato yield and quality has been previously examined, much of this research was conducted in hydroponic or greenhouse studies. The objective of this research was to examine the effect of N fertilizer sources (ammonium nitrate (NH_4NO_3), potassium nitrate (KNO_3), urea ($\text{CO}(\text{NH}_2)_2$), urea ammonium nitrate (UAN), and calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) on tomato (*Lycopersicon esculentum* Mill.) growth, yield, and fruit quality. The 2-year experiment was conducted using black plastic mulch covered raised beds with drip fertigation. A total of 180 lb/acre ($202 \text{ kg}\cdot\text{ha}^{-1}$) N was applied with each N source, with 25% applied preplant and premulch and remaining N applied as 10 weekly applications of 13.5 lb/acre ($15.2 \text{ kg}\cdot\text{ha}^{-1}$). If an N source contained Ca or K, that amount was applied to all other N sources (preplant and fertigated) as potassium chloride (KCl) or calcium chloride (CaCl_2). Collected data included plant height, leaf N concentration, and yield. Different N sources had varying and inconsistent effects on fruit yield and quality. Although plant height and stem diameter from UAN treatments were always smaller than those from other N sources, this effect did not extrapolate to decreased total marketable yield. Differences in N concentration of tomato leaf tissue were not consistent with N source and were not related to differences in tomato yield. There were few differences in yield

and quality of nonmarketable fruit due to N source. In this one-site, 2-year study, it appears that any of the N sources studied would be suitable for tomato production, if price of N fertilizer materials are the same.

The effect of different nitrogen (N) sources on crop growth and production has long been a topic of interest among scientists. Reasons for selecting a certain N form may be environmental, such as using positively charged ammonium forms to reduce leaching losses; may be economic, when a cheaper form of N is selected; or may be quality and quantity issues, when one form of N produces a better crop than another form.

Often, the source of fertilizer N becomes a nitrate (NO_3^-) versus ammonium (NH_4^+) issue. In greenhouse hydroponic studies, turnip (*Brassica rapa* L.) and watermelon (*Citrullus lunatus* Thumb.) growth was adversely affected by nutrient solution ratios high in NH_4^+ (Simonne et al., 1992, 1993). In both cases, plants expressed symptoms of NH_3 toxicity when grown in nutrient solutions that contained high levels of NH_4^+ .

Tomatoes grown in nutrient solution culture exhibited reduced vegetative growth as the NH_4^+ content of the NO_3^- to NH_4^+ ratio increased above 25% (Hartman et al., 1986). When any part of the N was supplied by NH_4^+ , the number of fruit formed at each flower cluster was not affected, but fruit weight was reduced and incidence of blossom-end rot increased. In another study, tomatoes grown in $(\text{NH}_4)_2\text{SO}_4$ had lower shoot dry weights than tomatoes grown in urea or $\text{Ca}(\text{NO}_3)_2$ at 4 weeks growth in nutrient solution (Barker and Corey, 1990). When the same experiment was conducted in soil (soil series was not provided), dry weight of tomato shoots grown in $(\text{NH}_4)_2\text{SO}_4$ was less than those grown in $\text{Ca}(\text{NO}_3)_2$. Using nutrient film techniques, Qasem and Hill (1993) demonstrated that NO_3^- N was the best N source for tomato plant growth, as shoot fresh and dry weight of tomato was reduced when plants were grown with urea or NH_4^+ N as the N source.

In field studies, the impact of NH_4^+ N nutrition on vegetable crop growth and yield is less clear. When

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comparing sodium nitrate (NaNO_3), $(\text{NH}_4)_2\text{SO}_4$, and NH_4NO_3 , fall yield of turnip greens was higher when N was supplied by NaNO_3 or NH_4NO_3 (del Valle and Harmon, 1970). There was no difference in spring yield among N sources. Conversely, yield of field-grown spinach (*Spinacea oleracea* L.) was higher with NH_4^+ N than NO_3^- N (Goh and Vityakon, 1983). A field study that compared NH_4NO_3 and various sulfur-coated ureas found no difference in tomato yield due to fertilizer material (Sharma et al., 1976). In the same study, one type of sulfur-coated urea produced lower yields of turnip greens than two other sulfur-coated ureas, NH_4NO_3 , or urea.

Other field studies found no difference in pepper (*Capsicum annuum* L.) plant dry weight at early fruit set as affected by N source (sulfur-coated urea (SCU), isobutylidene diurea (IBDU), ureaformaldehyde, urea, NH_4NO_3 , or $(\text{NH}_4)_2\text{SO}_4$) (Locascio et al., 1981). Marketable pepper yield was affected by an interaction between N source, N rate, and fertilizer placement (broadcast or banded). Highest yields were obtained when slow-release sources (SCU and IBDU) were applied under black plastic mulch at the highest N rate [200 lb/acre (225 kg·ha⁻¹)]. When broccoli yield and quality were evaluated, nitrate-containing N sources (NH_4NO_3 , $\text{Ca}(\text{NO}_3)_2$) increased yield over that obtained with ammonium sources ($(\text{NH}_4)_2\text{SO}_4$, urea) (Tremblay, 1989). However, this yield increase was matched by an increase of broccoli hollow stem, so the increased yield became a component of the nonmarketable portion of total yield.

Because much of the literature that examined the effect of N sources on vegetable yield and quality was confined to the greenhouse and conducted with a nutrient solution and sand culture, such results may not extrapolate to field conditions (Barker and Corey, 1990; Hartman et al., 1986; Simonne et al., 1992, 1993). Field research that examined N forms usually placed all of that fertilizer as preplant or split applications, and few of the materials were applied via drip fertigation (del Valle and Harmon, 1970; Locascio et al., 1981; Sharma et al., 1976). In one case, secondary nutrients applied with the N source (e.g., Ca in $\text{Ca}(\text{NO}_3)_2$) were not balanced across N sources that did not include

that nutrient, so confounding effects of nutrients other than N may not have been removed from the study (Tremblay, 1989). The objective of this study was to examine the effect of N source on field-grown, drip-fertigated stake tomato production yield and quality.

Methods and materials

The 2-year experiment was located at the E.V. Smith Horticultural Research Unit, near Shorter, Ala., on a Norfolk fine sandy loam (fine-loamy, siliceous thermic Typic Paleudult). 'Mountain Pride' tomatoes were grown on 6-inch (15-cm) raised beds covered with black plastic polyethylene mulch with drip irrigation installed (Twin-wall IV, 0.36-mm wall thickness, 0.23-m emitter spacing, Chapin Watermatics, Watertown, N.Y.). Planting beds were fumigated with 67% methyl bromide and 33% chloropicrin (CCl_3NO_2) at a rate of 200 lb/acre (225 kg·ha⁻¹) 2 weeks before transplanting. Transplants were greenhouse-grown plants, each grown in a 4.3-inch (10.9-cm) deep by 2.8-inch (7.1-cm) wide transplant cell filled with potting medium. All plants were hand-transplanted at 6 weeks of age into single rows of 25-ft (8.3-m) long plots with a within row spacing of 24 inches (60 cm). Between row spacing was 6 ft (2 m). Tomatoes were transplanted on 25 Apr. 1995 and 17 Apr. 1996. Recommended production practices for staked, fresh-market tomatoes were followed (Curtis et al., 1992; Kovach et al., 1992).

The experiment was arranged as a randomized complete-block design with N sources as treatments. Each treatment was replicated four times. Selected N sources were 1) calcium nitrate ($\text{Ca}(\text{NO}_3)_2$, 16N-0P-0K); 2) urea ($\text{CO}(\text{NH}_2)_2$, 45N-0P-0K); 3) ammonium nitrate (NH_4NO_3 , 34N-0P-0K); 4) urea ammonium nitrate solution (UAN, 32N-0P-0K); and 5) potassium nitrate (KNO_3 , 13N-0P-39K). A total of 180 lb/acre N was applied with each N source, with 25% [45 lb (20.5 kg)] applied as a preplant and premulch broadcast treatment and the remaining N applied as 10 weekly applications of 13.5 lb/acre (15.2 kg·ha⁻¹). Weekly N applications, which began 1 week after transplanting, were applied through drip irrigation tubing. If an N source also supplied K (e.g., KNO_3) or Ca, the amount of

that nutrient applied in the N treatment was also applied to the other N source treatments. Thus, a total of 253 lb/acre (284 kg·ha⁻¹) Ca was added to the urea, NH_4NO_3 , UAN, and KNO_3 treatments as CaCl_2 , and 538 lb/acre (603 kg·ha⁻¹) K was added to the $\text{Ca}(\text{NO}_3)_2$, urea, NH_4NO_3 , and UAN treatments as KCl. Calcium and potassium additions were added 25% preplant, with the rest was applied weekly in the drip fertigation treatments.

Weekly fertigation treatments started on 2 May 1995 and 29 Apr. 1996 and continued until 5 July 1995 and 1 July 1996. Additional irrigation was applied to maintain soil moisture at 0.20 to 0.25 bars (0.02 to 0.025 MPa), as indicated by soil tensiometers placed 6 inch (15 cm) deep in each replication. Additional fertility (P, K, Ca, and Mg) or lime was not applied, as yearly soil tests indicated there were adequate amounts of these nutrients for crop growth and development (Adams et al., 1994). Average soil pH was 6.5. The 1995 experiment was not located in the same area as the 1996 experiment.

Tomato harvest began on 22 June 1995 and 26 June 1996 and continued at ≈5-d intervals until 25 July 1995 and 22 July 1996. Fruit were harvested at the breaker stage (fruit just starting to turn color) or riper and then graded into U.S. Combination (highest quality), U.S. #3 (some cosmetic defects), and culls (unmarketable) (USDA, 1991). U.S. Combination grade fruit were separated according to diameter: jumbo [>3.5 inch (8.9 cm)], extra large [2.9 to 3.5 inch (7.4 to 8.9 cm)], large [2.5 to 2.9 inch (6.4 to 7.4 cm)], and medium [2.3 to 2.5 inch (5.8 to 6.4 cm)]. Yields were grouped into early (22 and 27 June 1995 and 26 June 1996), middle (29 June, 5 July, and 10 July 1995 and 1 and 9 July 1996) and late (19 and 25 July 1995 and 16 and 22 July 1996) season yields for statistical analysis and data reporting. All yields are reported as marketable yields (U.S. Combination plus U.S. #3 grades) per acre. In 1996, marketable and nonmarketable tomatoes were not size-separated due to labor constraints.

Twenty recently matured whole leaves (minus petioles) were sampled from each plot on 16 May, 6 June, and 22 June 1995 and 17 May, 11 June, and 1 July 1996. Leaves were oven-dried [113 °F (45 °C)], ground to pass

Table 1. Plant height and stem diameter of tomatoes as affected by date and N source (inches $\times$ 2.54 = cm).

N source	Plant ht (inches)					Stem diam (inches)		
	1995		1996					
	30 May	12 June	17 May	30 May	11 June	17 May	30 May	11 June
Ca(NO ₃) ₂	7.1 a ^z	10.4 a	15.0 a	17.6 a	20.0 a	0.48 a	0.60 a	0.60 ab
KNO ₃	6.8 b	10.3 a	15.7 a	19.1 a	20.8 a	0.50 a	0.63 a	0.63 ab
NH ₄ NO ₃	6.9 ab	10.5 a	15.7 a	19.0 a	21.3 a	0.51 a	0.62 a	0.67 a
Urea	6.8 b	10.6 a	15.4 a	19.3 a	21.5 a	0.50 a	0.64 a	0.65 a
UAN ^y	6.1 c	9.6 b	10.9 b	14.1 b	18.4 b	0.35 b	0.52 b	0.56 b

^zWithin each date, means not followed by the same letter are significantly different by Duncan's multiple range test at $\alpha = 0.05$.

^yUAN = urea ammonium nitrate.

a 100-mesh sieve, and analyzed for total N content via dry combustion techniques (Leco Corporation, St. Joseph, Mo.) (Bremner and Mulvaney, 1982). Five plants from each plot were randomly selected, and plant height (planting bed level to top of each plant) was measured on 30 May and 12 June 1995 and 17 May, 30 May, and 11 June 1996. In 1996, stem diameter readings were measured 2 inches (5.1 cm) above the planting bed using a micrometer.

Data were analyzed using appropriate analysis of variance techniques and mean separation by Duncan's multiple range test (SAS, 1989).

Results and discussion

Plant height and stem diameter were affected by N source (Table 1). In 1995 and 1996, tomato plants that received N as UAN were shorter with smaller stem diameters (1996) at all sampling dates. There were few other differences in plant size or stem diameter due to N source. The reason for this effect of UAN on plant growth is not known. The material has the same acidifying effect as NH₄NO₃ and urea, and its salt index is less than that of NH₄NO₃ (Foth and Ellis, 1988). Thus, plants from the UAN treatment should not be smaller because of excessive salt buildup or rapid increases or decreases in soil pH.

In both years, there were few significant differences in leaf N concentration due to N source (Table 2). In the first sampling of 1995, tomato leaves from plots receiving UAN had a higher N concentration than those receiving KNO₃. Whole plants from UAN treatments were shortest at this time (Table 1), so volume of plant tissue may be the cause of this higher N concentration.

Leaves sampled on 6 June 1995 did not have any significant differences in N concentration due to N source, even though whole plants in the UAN treatments were shorter at this time. Two weeks later (22 June), leaf N concentration had dropped in all treatments, likely a result of dilution as plants grew. At this sampling, leaves from the urea treatment had the lowest N concentration, with 0.28% less N than the highest N concentration found in leaves from the Ca(NO₃)₂ treatment.

In 1996, there was no difference in leaf N concentration at the first two sampling dates (Table 2). At the last sampling, leaves from Ca(NO₃)₂ treatments had the highest N concentration compared to any other N source. Tomato leaves sampled from urea, KNO₃, and NH₄NO₃ treatments had similar low N concentrations, an average of 2.58%. Leaves from the urea treatment had the lowest N concentra-

tion, 0.54% less than leaves sampled from the Ca(NO₃)₂ treatment, which was similar to the last sampling of 1995.

Nitrogen sufficiency levels of tomato leaves in both years of the study were usually within published values. Typical N sufficiency values for field-grown tomatoes at midbloom have been reported at 4.0% to 6.0% (Jones et al., 1991). Hydroponic, greenhouse-grown tomatoes exhibited N concentrations of 3.08% to 4.91% at first harvest (56 d) and 2.61% to 4.23% at third harvest (90 d). In that study, N concentration varied with the NO₃⁻ to NH₄⁺ ratio of the nutrient solution (Hartman et al., 1986). In the present study, leaf N concentrations at the final 1996 sampling were below published N sufficiency levels; however, this sampling was only 24 d before last fruit harvest, and plant growth and fruit production would account for dilution of N concentration in the plant leaf.

Because total N was determined via dry combustion, NH₄⁺ N and NO₃⁻ N would be included in the measure of total N produced by that process (Bremner and Mulvaney, 1986). This is unlike semimicro Kjeldahl digestion, where NO₃⁻ N in the plant tissue is not determined (Isaac and Johnson, 1976) and must often be determined by a separate extraction (Mills, 1980).

Table 2. Total N concentration of tomato leaves as affected by date and N source.

N source	N concn (%)					
	1995			1996		
	16 May	6 June	22 June	17 May	11 June	1 July
Ca(NO ₃) ₂	5.19 ab ^z	5.77 a	4.64 a	5.23 a	5.23 a	3.03 a
KNO ₃	4.95 b	5.60 a	4.43 ab	5.84 a	4.63 a	2.68 bc
NH ₄ NO ₃	5.09 ab	5.57 a	4.48 ab	5.45 a	4.42 a	2.58 bc
Urea	5.36 ab	5.55 a	4.36 b	5.22 a	5.22 a	2.49 c
UAN ^y	5.52 a	5.84 a	4.58 ab	5.82 a	5.15 a	2.76 b

^zWithin each date, means not followed by the same letter are significantly different by Duncan's multiple range test at $\alpha = 0.05$.

^yUAN = urea ammonium nitrate.

Previous research that examined N sources and their effect on N content of pepper concluded that using Kjeldahl N without considering the effect of N form could be a misleading diagnostic tool (Hartman et al., 1986). Since this research determined N concentration via dry combustion, comparison of total N in plant tissue as affected by N source would be valid.

In 1995, N source did not affect marketable yield (Table 3). There were no significant N source $\times$ harvest date interactions (data not shown). When total marketable yield was separated by grade and harvest date, yield differences in selected grades due to N source occurred on only two occasions (data not shown). Early-season yield of large tomatoes from UAN treatments was 55% greater than those from $\text{Ca}(\text{NO}_3)_2$, urea, or KNO_3 treatments. Midseason yield of US #3 tomatoes from urea and UAN treatments were 972 lb/acre (1,089 kg·ha⁻¹) higher than yields from KNO_3 , $\text{Ca}(\text{NO}_3)_2$, or NH_4NO_3 treatments [average of 2267 lb/acre (2,539 kg·ha⁻¹)].

Harvest date significantly affected marketable yield in 1995, with total yield increasing over time up to the late season harvest (Table 3). Maximum yield of jumbo tomatoes occurred at midseason, while maximum yield of extra large, large, medium, and US #3 tomatoes all occurred at the late season harvest. Average total marketable yield of tomatoes for the 1995 harvest year was 32,119 lb/acre (35,973 kg·ha⁻¹), higher than the 5-year statewide average of 18,866 lb/acre (21,130 kg·ha⁻¹) for stake tomato

production (Alabama Department of Agriculture and Industries, 1995).

There were few differences in unmarketable yield among N sources in 1995, and there was no significant N source $\times$ harvest date interaction (data not shown). Unmarketable yield of tomatoes grown in $\text{Ca}(\text{NO}_3)_2$ was greater than yield of tomatoes grown in NH_4NO_3 , but unmarketable yield of tomatoes grown in the other N sources was unaffected by N source. When analyzed by harvest date and fruit defects (blossom-end rot, insect damage, disease, or other damage) late season fruit from the $\text{Ca}(\text{NO}_3)_2$ treatment had 20% more insect damage than fruit from KNO_3 treatments (data not shown). No other N source affected fruit defects. Greatest yield of the other category of damaged fruit occurred at the early season harvest, mostly due to sun-scalded fruit not shaded by smaller tomato plants. This was not affected by N source. Average total unmarketable yield of tomato was 4003 lb/acre (4,483 kg/ha), 11% of the total tomato yield.

In 1996, yield of marketable and unmarketable tomatoes were affected by a N source $\times$ harvest date interaction ($P < 0.05$) (Table 4). When analyzed by harvest date, this interaction appears to be largely a result of the UAN treatment, which produced either no or reduced fruit yield at the early season harvest, yet had the greatest yield at the late season harvest. Tomato yield from the remaining N source treatments reached peak yield at the midseason harvest.

Total marketable yield of tomato

from KNO_3 treatments was 54% greater than yield of tomato from $\text{Ca}(\text{NO}_3)_2$ and UAN treatments. There was no difference in fruit yield from KNO_3 , NH_4NO_3 , or urea treatments, and all three of these N source treatments outyielded the $\text{Ca}(\text{NO}_3)_2$ treatment. Average marketable yield of tomato in 1996 was 20,166 lb/acre (22,586 kg·ha⁻¹).

When examined by harvest date, there were no clear yield differences in marketable yield due to one particular N source. At the early season harvest, there were no tomatoes harvested from UAN treatments, and tomato yield from the four remaining N source treatments was not significantly different from each other. At the midseason harvest, every N source treatment produced a higher tomato yield than the UAN treatment, and yield from the $\text{Ca}(\text{NO}_3)_2$ treatment was lower than that from NH_4NO_3 , KNO_3 , and Urea treatments. Late season tomato yield from the UAN treatment was greater than from any other N source, a reverse of results observed at the early and midseason harvests. It appears that in 1996 UAN delayed earliness of tomato yield.

Average total unmarketable yield in 1996 was 5650 lb/acre (6,328 kg·ha⁻¹), 22% of total tomato yield. There were no clear differences in yield of unmarketable fruit due to N source, and unmarketable yield responses due to N source changed at each harvest date. Unmarketable yield of tomato grown in KNO_3 , NH_4NO_3 , or urea were never significantly different from each other. Yield of unmarketable to-

Table 3. Marketable and nonmarketable tomato yield as affected by N source and harvest date in 1995 (lbs/acre $\times$ 1.12 = kg·ha⁻¹).

N Source	Harvest date			
	Early season	Midseason	Late season	Total
Marketable yield (lb/acre)				
Ca(NO ₃) ₂	5,126 a ^z	10,640 a	15,968 a	31,734 a
KNO ₃	5,247 a	10,097 a	15,887 a	31,237 a
NH ₄ NO ₃	5,628 a	10,251 a	19,320 a	35,199 a
Urea	4,510 a	11,781 a	15,393 a	31,684 a
UAN ^x	5,781 a	10,583 a	14,381 a	30,745 a
Nonmarketable yield (lb/acre)				
Ca(NO ₃) ₂	1,117 a ^z (17.9) ^y	866 a (7.5)	2,858 a (15.2)	4,841 a (13.2)
KNO ₃	1,190 a (18.5)	389 a (3.7)	2,559 a (13.9)	4,138 ab (11.7)
NH ₄ NO ₃	1,020 a (15.3)	543 a (5.0)	1,498 a (7.2)	3,061 b (8.0)
Urea	1,085 a (19.4)	785 a (6.2)	2,316 a (13.1)	4,186 ab (11.7)
UAN	1,053 a (15.4)	826 a (7.2)	1,911 a (11.7)	3,790 ab (11.0)

²Within each date and quality category, means not followed by the same letter are significantly different by Duncan's multiple range test at $\alpha = 0.05$.

³Numbers in parentheses are nonmarketable yield expressed as a percent of total yield.

⁴UAN = urea ammonium nitrate.

Table 4. Marketable and nonmarketable tomato yield as affected by N source and harvest date in 1996 (lbs/acre $\times$ 1.12 = kg-ha⁻¹).

N source	Harvest date			
	Early season	Midseason	Late season	Total
Marketable yield (lb/acre)				
Ca(NO ₃) ₂	1,717 a ^z	9,846 b	1,198 b	12,761 c
KNO ₃	1,296 a	17,360 a	6,704 b	25,360 a
NH ₄ NO ₃	1,198 a	16,988 a	5,668 b	23,854 ab
Urea	907 a	16,648 a	6,802 b	24,357 ab
UAN ^x	0 b	2,397 c	12,097 a	14,494 bc
Nonmarketable yield (lb/acre)				
Ca(NO ₃) ₂	138 a ^z (7.4) ^y	3,336 ab (25.3)	850 b (41.5)	4,324 b (25.3)
KNO ₃	275 a (17.5)	4,834 a (21.8)	2,397 ab (26.3)	7,506 a (22.8)
NH ₄ NO ₃	235 a (16.4)	3,320 ab (16.3)	2,478 ab (30.4)	6,033 ab (20.2)
Urea	186 a (17.0)	3,668 ab (18.1)	2,065 ab (23.3)	5,919 ab (19.6)
UAN	49 a (100.0)	955 c (28.5)	3,466 a (22.3)	4,470 b (23.6)

^zWithin each date and quality category, means not followed by the same letter are significantly different by Duncan's multiple range test at $\alpha = 0.05$.

^yNumbers in parentheses are nonmarketable yield expressed as a percent of total yield.

^xUAN = urea ammonium nitrate.

tomatoes from the UAN treatment behaved similarly to those from the marketable segment—lower yields at early harvest dates followed by a higher yield at the last harvest.

Few yield or quality trends due to N source are obvious in the 2 years of this study. Although plant height and stem diameter of tomatoes from the UAN treatment were always significantly smaller than those from other N source treatments, this effect did not extrapolate to decreased total marketable yield at the end of each harvest season. In 1996, however, plants grown in the UAN treatment had delayed maturity, as yield of tomatoes from that treatment was reduced until the last harvest date, at which point the greatest percentage of total yield was produced. Such an effect should be considered if timeliness to a certain market is as important as maximum yield.

Varying results such as observed in this 2-year experiment have been observed in other field-scale N source research. A recently completed study that examines different N sources for lettuce (*Lactuca sativa* L.) production found no response to N source ((NH₄)₂SO₄, NH₄NO₃, or Ca(NO₃)₂) (Sanchez and Obeker, 1997). In another study interactions between N source, N rate and mulch made it difficult to separate treatment effects, although a slow-release N source applied at high N rates under mulch did produce highest yields (Locascio et al., 1981). Such a yield response, however, could be related to the timeliness of N application (via slow release) rather

than the N source itself. One field study that applied N sources (Ca(NO₃)₂, UAN, or NH₄NO₃) through drip irrigation found no significant consistent differences due to N source for tomato or pepper marketable or total yield, fruit size, or blossom-end rot (Maynard, 1997). As a general statement, it has been noted that field production in well-buffered soils with a pH range of 5 to 7 should not produce detrimental side effects related to ammonium nutrition (Marschner, 1986).

In field-based research, different N sources had varying and inconsistent effects on yield and quality of fruit or vegetables (Goh and Vityakon, 1983; Locascio et al., 1981; Maynard, 1997; Sanchez and Obeker, 1997). This varies from hydroponic or solution-based research, which usually found that differences in nitrate- or ammonium-based nutrition affected crop quality or yield (Hartman et al., 1986; Simonne et al., 1992, 1993). Observed differences may be due to the solution media used for the research; as a hydroponic system represents a well-controlled production system unregulated by soil-based biological processes. In comparison, season-long growth of a field crop is influenced by the highly active biological processes of N mineralization and immobilization. Over a growing season, the conversions of N mediated by these processes may be of greater importance in influencing the N form available for plant uptake than the source of fertilizer N itself.

Conclusion

In this limited study (one site, 2 years), yield and quality of field stake tomatoes grown on raised beds with drip irrigation was only slightly affected by the type of N source applied through the drip irrigation line. Although plants grown in UAN were shorter and had less early yield (1996 only) than plants receiving other N sources, total yield of tomato was not affected by the UAN treatment. There were few differences in yield and quality of unmarketable fruit due to N source. In this study, it appears that any of the N sources—Ca(NO₃)₂, UAN, Urea, KNO₃, or NH₄NO₃—would make suitable N sources for tomato production when total marketable yield is a primary concern.

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