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Nitrogen Concentrations Affect Pepper Yield and Leachate Nitrate-nitrogen from Rockwool Culture

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Abstract. **Experiments were conducted to determine the effect of varying solution N concentrations on fruit yield and NO_3-N concentration in leachate from rockwool-grown 'Midal' peppers (*Capsicum annuum* L.) in Florida. Treatment 1 plants received a series of nutrient solutions containing N at 60, 90, and 120 mg·liter^{-1} (60–90–120 mg·liter^{-1}) during their growth cycle. Plants in treatments 2 and 3 were grown with N at 120 or 175 mg·liter^{-1}, respectively, throughout their entire growth cycle. Two trials were conducted; trial 1 from 17 Nov. 1991 to 1 July 1992, and trial 2 from 31 July 1992 to 23 Feb. 1993. In both trials, total marketable fruit weight was significantly ($P \leq 0.05$) higher (16% to 67%) for plants grown with N at 175 than with 60–90–120 mg·liter^{-1}. In trial 2, plants receiving N at 175 mg·liter^{-1} produced significantly more fruit (8%) and 14% higher total fruit weight than plants receiving N at 120 mg·liter^{-1}. The trend toward higher yield with N at 175 rather than 120 mg·liter^{-1} also occurred during trial 1, but differences were not significant. Nitrogen concentration did not significantly affect the percentage of total fruit having blossom-end rot in either trial (41% in trial 1; 13% in trial 2). Nitrogen at 175 mg·liter^{-1} resulted in 10% to 40% increases in total nutrient solution use and 2.5- to 3.5-fold increases in leachate NO_3-N concentration compared to N at 120 mg·liter^{-1}.**

Hydroponic greenhouse vegetable producers strive to optimize growing conditions to maximize economic returns. To achieve this goal, essential nutrients must not be limiting to crops. However, if a reduction in use of a macronutrient, such as N can be accomplished without reducing yields, this could mean savings to the grower in fertilizer costs and decreased concern over leaching of excess nitrates into groundwater. In recent years, the impact of agriculture on groundwater quality has been closely scrutinized by the public and policymakers in the United States and Europe (Biernbaum, 1992; Cartwright et al., 1991). According to Biernbaum (1992), the key to reducing groundwater contamination by nitrates due to leaching or runoff from greenhouses is to clearly define water and nutrient requirements of plants.

Nutrient recommendations for greenhouse production of vegetable crops vary. For example, although N at 200 mg·liter^{-1} is a typical recommendation for growing hydroponic tomatoes (*Lycopersicon esculentum* Mill.) in Canada (Mohyuddin, 1987), Hochmuth (1991) has recommended a five-step solution for growing tomatoes in Florida that starts with N at 70 mg·liter^{-1} during the vegetative stage and increases N to 150 mg·liter^{-1} during heavy fruit set. He noted that this recommendation also can decrease blossom-end rot (BER), because high N during early stages of plant development can lead to excess vegetative growth and a higher incidence of BER. Bakker (1989) used N at 175 mg·liter^{-1} for peppers grown in rockwool in the Netherlands. Our experiments were designed to determine the effects of three solution-N concentrations on yield and leachate NO_3-N concentration from rockwool-grown peppers in Florida. The effect of N concentration on BER occurrence and nutrient solution use also was studied.

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Materials and Methods

Conditions for plant growth (trial 1). 'Midal' pepper seeds were sown in 35 × 35 × 38-mm rockwool cubes (Agrodynamics, New Brunswick, N.J.) on 17 Nov. 1991, and germinated seedlings in cubes were set into 76 × 76 × 64-mm rockwool blocks 10 days later when seedlings were 10 to 12 cm tall with four true leaves. All experiments were conducted in a greenhouse with a dual polyethylene roof and polycarbonate siding under natural photoperiod conditions in Florida. Seedlings were irrigated with a complete nutrient solution containing N at 60 mg·liter^{-1} (Table 1; treatment 1, step 1) to maintain the rockwool at moisture capacity. Plants were transplanted onto 51 × 152 × 914-mm, rockwool growing slabs (two seedlings per slab) on 13 Dec. 1991 and assigned randomly to one of three treatments. Treatment 1 plants received a three-step series of nutrient solutions containing N at 60, 90, and 120 mg·liter^{-1} (60–90–120 mg·liter^{-1}) during successive phases of the growth cycle (Table 1); N was increased from 60 to 90 mg·liter^{-1} and from 90 to 120 mg·liter^{-1} when weekly sampling of the slab solution indicated that average NO_3-N concentration had fallen to <15 mg·liter^{-1}. Duration of steps 1, 2, and 3 was 6, 5, and 18 weeks, respectively. Mean air temperatures in the greenhouse during steps 1, 2, and 3 were 21.6, 21.1, and 23.0C, respectively.

In treatment 1, K, Ca, Mg, and S concentrations also were increased with each increase in N to maintain adequate concentrations of these nutrients (Hochmuth, 1991). Plants in treatments 2 and 3 were grown with N at a constant 120 or 175 mg·liter^{-1}, respectively, with all other nutrients at the same levels as in treatment 1, step 3 (Table 1). Increasing solution-N concentration from 60 to 90 mg·liter^{-1} in treatment 1 and from 120 to 175 mg·liter^{-1} in treatment 2 vs. treatment 3 was achieved without increasing the concentrations of the other nutrients. To accomplish this, we increased $Ca(NO_3)_2$ and decreased $CaCl_2$ in the formulations. Chloride concentrations in the resulting solutions ranged from 50 to 145 mg·liter^{-1}. Sonneveld and van der Burg (1991) reported that the yield of sweet peppers grown in hydroponic solutions was not affected by increasing Cl from 5 to 12.5 mmol·liter^{-1} (177 to 444 mg·liter^{-1}). Therefore, it is unlikely that the range of Cl concentrations that were used in our experiments affected our pepper yields. The pH of all solutions was adjusted to 5.5 using nitric acid. The final NO_3-N : NH_4-N ratio in all treatments was 95:5.

Treatments were arranged in a randomized complete-block design with 24 blocks, one experimental unit (slab) per treatment in each block. Plants were irrigated 10 times per day for 3 min during the first 2 weeks following transplanting onto the growing slabs. A weighing lysimeter controlled irrigation frequency for each treatment thereafter (Burns et al., 1990). An irrigation event was triggered by a 500-ml depletion of nutrient solution from the slab via evapotranspiration. Each irrigation event replaced the depleted 500 ml and provided an additional 200 ml to allow leachate from the slab. To maintain acceptable slab pH and nutrient balance, enough solution was provided to allow at least 15% to 20% of the total volume to drain (Smith, 1987). Prior work in our greenhouses indicated that leaching 29% of the total volume was necessary to maintain slab pH in an acceptable range.

Emitter flow rates were calibrated to within 10% of the mean flow rate for each treatment by irrigating for 3 min and measuring the volume of solution delivered to each slab (two emitters). Total nutrient solution use per

Table 1. Nutrient formulations (in mg·liter^{-1}) for 'Midal' peppers grown in rockwool (treatment 1).[z, y]

Nutrient	Step 1	Step 2	Step 3
N	60	90	120
P	50	50	50
K	150	150	180
Ca	150	150	180
Mg	40	40	60
S	50	50	60

[z]Treatment 2: step 3 solution used throughout life cycle; treatment 3: N at 175 mg·liter^{-1}; all other nutrients same as in step 3.
[y]Iron, Cu, Mn, Zn, B, and Mo were provided in all solutions at the following concentrations: 2.0, 0.2, 0.8, 0.3, 0.5, and 0.05 mg·liter^{-1}, respectively.

rockwool slab (two plants) was calculated for each treatment by multiplying the total number of irrigation events triggered by each lysimeter by 0.5 liters.

Wettable S (7.2 g•liter^{-1}) was applied weekly as a foliar spray to prevent broad mite (*Polyphagotarsonemus latus* Banks) infestation. No other pesticides were applied to the plants during the experiment.

Analysis of leachate and slab samples. Five randomly selected slabs from each treatment were placed in plastic trays designed to catch and channel nutrient solution draining from the slab (leachate) into a collection sump. A 10-ml sample was collected daily from each sump, and daily samples were combined into one weekly sample per treatment. Nutrient solution also was drawn from nine randomly selected growing slabs (three per treatment) twice a week using a syringe and spinal needle. Samples were analyzed for pH (values ranged from 5.5 to 7.8) and electrical conductivity (values ranged from 0.9 to 2.9 mS•cm^{-1}). The two weekly samples from each slab were combined into one sample for NO_3-N analysis. An ion chromatograph (model 4500i; Dionex, Sunnyvale, Calif.) was used to determine NO_3-N concentration in leachate and slab samples.

Nutrient analysis of tissue. Leaf samples were collected during vegetative (while treatment 1 plants were receiving step 1 solution), early fruit (while treatment 1 plants were receiving step 2 solution), and late fruit (1 week before the final harvest) growth stages. Each sample consisted of the eight most recently matured leaves plus petioles (two leaves per plant, two plants per slab from two slabs). Leaves were washed in tap water, rinsed three times in deionized water, and dried for 48 h at 60C. Plant tissue was analyzed at the Soil and Plant Analysis Laboratory, Madison, Wis. Tissue was analyzed for total N using a semimicro Kjeldahl procedure. Following HNO_3-$HClO_4$ digestion, all other nutrient concentrations were determined using an inductively coupled plasma (ICP) emission spectrometer (Fison model 34000; Applied Research Laboratories, Valencia, Calif.). Mature red fruit (eight per treatment) were prepared and analyzed as indicated previously for leaf samples.

Growth and yield data. Plant height at 1 month and 3 months after transplanting was recorded for 10 randomly chosen plants (replications) per treatment. Number of days from the time of transplanting to first flower and to the first 2.5-cm-long fruit also were determined for the 10 replications. During the first harvest, on 26 Feb. 1992, the first whorl of fruit (color breaking stage) was thinned to three fruit per plant. Thereafter, mature-red fruit were harvested weekly through 1 July 1992; BER-affected fruit were removed as external symptoms appeared on the fruit. All fruit maturing without BER symptoms were considered marketable. Weight and number of marketable fruit per slab (two plants) and number of BER fruit per slab were recorded weekly.

All data were analyzed using SAS general linear models procedure (Littell et al., 1991); the Student–Newman–Keuls test was used for mean separation. Significance is indicated if $P \leq 0.05$.

Trial 2. Seeds were sown on 31 July 1992, and seedlings were transplanted onto the growing slabs on 27 Aug. 1992. Duration of steps 1, 2, and 3 was 5, 3, and 17 weeks, respectively. Mean air temperatures in the greenhouse during steps 1, 2, and 3 were 25.6, 23.6, and 22.8C, respectively. The initial harvest to thin the first whorl of fruit was on 20 Oct. 1992, and weekly harvests continued through 23 Feb. 1993. Data similar to those in trial 1 were recorded, with the following exceptions: fruit were not analyzed for nutrient content and mature fruit from four harvests (five to eight per treatment) were analyzed for soluble solids concentration on a digital refractometer (Atago, Tokyo).

Results and Discussion

By 3 months after transplanting, pepper plants grown with N at 60–90–120 mg•liter^{-1} were significantly shorter in both trials than those grown with either 120 or 175 mg•liter^{-1} (trial 1, 127 vs. 137 and 138 cm; trial 2, 117 vs. 139 and 146 cm). Nitrogen treatment did not affect the average number of days from transplanting to first flower (trial 1, 29 days; trial 2, 24 days) or to first fruit (trial 1, 38 days; trial 2, 31 days) during either trial. A greenhouse study conducted by Thomas and Heilman (1967) found that increasing N (0, 40, 80, or 120 mg•liter^{-1}) in the irrigation supply to potted sweet pepper plants increased shoot dry matter but did not affect flower initiation. Leskovar et al. (1989) reported that shoot and root growth variables responded positively and linearly to N rate when peppers were grown in sand culture with N at 56, 84, or 112 mg•liter^{-1}.

In trial 1, after 1 month of harvesting, neither number nor weight of marketable fruit was affected by N treatment (data not presented). After 2 months (early harvest), marketable fruit count was still not affected, but marketable fruit weight produced with N at 60–90–120 mg•liter^{-1} was significantly lower than with the other two N treatments (Table 2). Increasing N did not affect the total number of marketable fruit produced for the season, but total marketable fruit weight was 16% higher for plants grown with N at 175 than at 60–90–120 mg•liter^{-1}. Plants grown with N at 175 mg•liter^{-1} produced fruit that were 7% larger than fruit from plants fertilized with the other two treatments. However, there was no significant difference in total marketable fruit weight between plants grown with N at 120 or 175 mg•liter^{-1} (Table 2). A field experiment with ‘California Wonder’ bell peppers showed similar results; applying N increased fruit yield, but there was no yield difference between the two highest treatments (120 and 180 kg N/ha) (Hegde, 1989). In a field study with ‘New Mexico 6-4’ chili peppers, Stroehlein and Oebker (1979) concluded that moderate N rates produced the highest yields and also the most desirable plants, with higher N treatments promoting taller plants with abundant foliage.

In trial 2, a significant reduction (36%) in marketable fruit weight was evident after just 1 month of harvest when comparing plants grown with N at 60–90–120 mg•liter^{-1} to those at a constant 120 mg N/liter (data not presented). After 2 months of harvest, plants grown with 60–90–120 mg•liter^{-1} were producing significantly fewer peppers and a lower marketable fruit weight than the other two treatments (Table 2). Plants grown with the step solutions continued to produce less fruit throughout the experiment and also produced significantly smaller fruit than plants grown with N at either 120 or 175 mg•liter^{-1}.

Reductions of early and total yields in both trials with 60–90–120 mg•liter^{-1} may indicate that the N levels provided to the plants in the

Table 2. Effect of solution N concentrations on marketable fruit yield and occurrence of blossom-end rot (BER) in ‘Midal’ pepper grown in rockwool.

		Marketable fruit					BER fruit			
	N	Early harvest[z]		Total harvest			Early harvest[z]		Total harvest	
Treatment	(mg•liter^{-1})	No.	Wt (kg)	No.	Wt (kg)	Wt/fruit (kg)	No.	% Total[y]	No.	% Total[y]
					Trial 1					
1	60–90–120	11.2 a[x]	1.67 a	27.4 a	3.83 a	0.14 a	3.7 a	23.6 a	19.3 a	40.6 a
2	120	12.0 a	1.91 b	28.9 a	4.17 ab	0.14 a	5.3 a	27.2 a	22.5 a	41.8 a
3	175	11.9 a	2.01 b	29.9 a	4.45 b	0.15 b	4.9 a	26.5 a	22.4 a	42.0 a
					Trial 2					
1	60–90–120	10.5 a	1.15 a	18.2 a	2.10 a	0.12 a	<0.1 a	0.4 a	1.9 a	8.9 a
2	120	13.1 b	1.81 b	23.2 b	3.07 b	0.13 b	1.8 b	12.3 b	3.9 b	14.1 a
3	175	11.9 b	1.78 b	25.1 c	3.51 c	0.14 b	3.0 c	19.1 c	4.5 b	14.8 a

[z]Totals for 2 months.

[y]Percentage of total harvest = number of BER fruit × 100/total fruit count (marketable + BER).

[x]All means represent two plants and are the mean values from 15 to 24 replicates. Within a trial, mean separation within columns at $P \leq 0.05$ by Student–Newman–Keuls test.

Table 3. Effect of solution-N concentrations on nutrient concentrations (percent) in leaves of most recently matured 'Midal' peppers removed during vegetative, early fruit, and late fruit stages.

Treatment	N ($mg \cdot liter^{-1}$)	Trial 1 N	Trial 1 P	Trial 1 K	Trial 1 Ca	Trial 1 Mg	Trial 2 N	Trial 2 P	Trial 2 K	Trial 2 Ca	Trial 2 Mg
					Vegetative stage						
1	60–90–120	4.3 a[z]	0.63 a	4.5 a	2.0 a	0.50 a	4.3 a[z]	0.54 a	5.4 a	2.3 a	0.67 a
2	120	5.3 b	0.65 b	5.1 b	1.8 b	0.57 b	5.3 b	0.56 ab	5.9 b	2.4 a	0.73 b
3	175	5.6 c	0.66 b	5.4 b	1.9 c	0.60 c	5.8 c	0.58 b	5.6 a	2.4 a	0.84 c
					Early fruit stage						
1	60–90–120	4.6 a	0.47 a	5.1 a	2.4 a	0.49 a	3.7 a	0.33 a	6.2 a	3.1 a	0.90 a
2	120	4.8 b	0.56 b	4.7 b	2.1 b	0.58 b	4.4 b	0.33 a	5.9 b	3.1 a	1.11 b
3	175	5.0 c	0.56 b	4.0 c	2.2 b	0.60 b	4.9 c	0.37 b	5.5 c	3.1 a	1.31 c
					Late fruit stage						
1	60–90–120	4.5 a	0.33 a	5.5 a	1.9 a	0.48 a	5.2 a	0.53 a	9.6 a	2.7 a	0.66 a
2	120	4.5 a	0.31 a	5.5 a	2.1 b	0.53 b	5.2 a	0.48 b	10.1 a	2.7 a	0.65 a
3	175	4.6 a	0.32 a	5.3 a	2.2 b	0.50 ab	5.3 a	0.37 b	9.5 a	2.3 b	0.56 b

[z]Within a growth stage, means in the same column with different letters are significantly different at $P \leq 0.05$ by Student–Newman–Keuls test.

early stages of development were not adequate or that the N concentration should have been increased to the next step at a slab N concentration higher than 15 $mg \cdot liter^{-1}$. Slab N concentration was monitored for three slabs per treatment, and the mean was used to determine when the N level should be increased to the next step. Due to variability in nutrient uptake by plants from slab to slab, some slabs may have gone through a period when N available to the plant roots was considerably <15 $mg \cdot liter^{-1}$. However, there is evidence that low N concentrations are adequate to maintain yields in hydroponic culture if the N is available to the root systems at all times. Tomato plants grown in recirculating, flowing solutions containing NO_3-N at 10, 20, 40, 80, 160, or 320 $mg \cdot liter^{-1}$ produced similar total fruit weights (Massey and Winsor, 1980). Perhaps the step solution recommended for tomatoes in which N ranges from 70 to 150 $mg \cdot liter^{-1}$ (Hochmuth, 1991) would be adequate to maintain the yield potential of 'Midal' peppers.

In trial 2, plants grown with N at 120 or 175 $mg \cdot liter^{-1}$ had similar yields during the first half of the growing season and a similar average fruit size throughout the growing season (Table 2). However, total marketable fruit count and weight were 8% and 14% higher, respectively, for plants grown with N at 175 $mg \cdot liter^{-1}$. Field studies conducted by Stroehlein and Oebker (1979) revealed that chili peppers responded to higher N rates by producing larger but fewer mature fruit. Maynard et al. (1962) reported that peppers grown in sand culture had significantly more fruit set as N concentrations were increased from 100 to 400 $mg \cdot liter^{-1}$. Massey and Winsor (1980) also reported an increase in number of tomato fruit per plant as they increased N concentration in recirculating hydroponic solutions. Contrary to our results, they found that increased N concentrations were accompanied by a reduction in fruit size.

BER was common in trial 1, affecting from 25% to 33% of early harvest, and causing >40% loss of total yield (Table 2). Nitrogen treatments did not consistently affect the mean Ca concentration (0.06% to 0.08%) in fruit sampled during the final 2 months of harvest or the occurrence of BER in this trial. However, in trial 2, each increase in N concentration

Table 4. Solution-N concentrations affect NO_3-N in leachate and total nutrient solution use by 'Midal' peppers grown in rockwool.

Treatment	N ($mg \cdot liter^{-1}$)	Nutrient solution use (liters/two plants)	NO_3-N in leachate ($mg \cdot liter^{-1}$)
		Trial 1	
1	60–90–120	173	48 ± 5.0[z]
2	120	183	57 ± 3.9
3	175	200	141 ± 5.1
		Trial 2	
1	60–90–120	130	25 ± 3.9
2	120	160	37 ± 5.9
3	175	224	131 ± 6.3

[z]Mean values represent 21 to 25 samples.

caused a significantly higher incidence of BER during the first 2 months of fruit production. The two higher N concentrations produced significantly more fruit with BER for the season than 60–90–120 $mg \cdot liter^{-1}$, but the difference in BER as a percentage of total fruit was not significant (Table 2). Although Raleigh and Chucka (1944) reported that high N fertilization increased BER occurrence in tomato fruit, Pill et al. (1978) found that increasing N levels had no effect on tomato fruit Ca concentrations. They obtained BER only when all N was provided as NH_4-N. In our experiments, only 5% of the N was provided as NH_4-N.

The percentage of fruit that was affected by BER ranged from 9% to 15% of the total harvest in trial 2, compared to >40% in trial 1 (Table 2). There was a lower average temperature during step 2 (early fruiting stage) of trial 1 compared to trial 2 (21.1 vs. 23.6C) and higher average relative humidity (RH) during step 2 (81% vs. 75%) and step 3 (late fruiting stage) (83% vs. 68%) of trial 1 compared to trial 2. Lower temperatures and higher RH during the reproductive phase of growth may have decreased the transpiration rate of peppers in trial 1 compared to trial 2, thereby decreasing Ca movement to developing fruit and increasing BER. Also, average light intensity during step 3 of trial 1 (341.5 $\mu mol \cdot s^{-1} \cdot m^{-2}$) was almost double that during trial 2. High light intensity often increases the severity of Ca-related fruit disorders (Shear, 1975).

Fruit N concentration ranged from 1.78% to 1.99% and was not affected by N treatments. Also, N treatments did not significantly affect the soluble solids concentration of fruit, which ranged from 5.5% to 6.9%.

Leaf N concentration increased significantly with each increase in N application during the vegetative and early fruit stages of both trials (Table 3). However, by the late fruit stage, there was no difference in leaf N concentration among the three N treatments. No N deficiency symptoms were observed in any of the pepper plants. Hochmuth et al. (1991) described the adequate range for leaf N concentrations for vegetative, early fruit set, and early harvest stages of peppers as 4.0% to 5.0%, 2.9% to 4.0%, and 2.5% to 3.0%, respectively. Reuter and Robinson (1986) list 2.9% to 4.6% leaf N as an adequate range for bell peppers during early fruiting. In our studies, the percentages of N in pepper leaves were within or well above the established adequate ranges for soil-grown peppers during all growth stages, regardless of N treatment (Table 3). Because N treatments resulted in significantly different final yields, the acceptable leaf N concentrations for hydroponically grown peppers may need to be reevaluated.

Thomas and Heilman (1964) reported that the percentage of P in pepper leaf tissue was negatively correlated with N level. This relationship was not evident with P in our experiments but was true for leaf K concentration during early fruit stages of both trials (Table 3). Leaf Ca concentrations were not consistently affected by N, but leaf Mg concentrations significantly increased with increases in leaf N during vegetative and early fruit stages of both trials (Table 3). Leaf micronutrient concentrations were not consistently affected by increasing N levels (data not presented).

The total amount of nutrient solution applied per rockwool slab (two plants), as measured by the weighing lysimeter, increased as the amount of N provided to the plants increased (Table 4). Solution use was 10% and 40% greater for plants provided N at 175 mg•liter^{-1} than for those provided N at 120 mg•liter^{-1} in trials 1 and 2, respectively. Leskovar et al. (1989) reported that N stimulated root and shoot growth of peppers grown in sand culture. Therefore, more solution use by plants provided with higher N concentrations may have been due to increased capability for uptake by a presumed increase in root area and higher water demand because of increased shoot area.

Increases in N supplied to the plants resulted in increased NO_3-N concentration in the leachate solution draining from the rockwool slabs (Table 4). During steps 1 and 2, NO_3-N concentration in the leachate from the step solution slabs was one-half to one-third that from slabs provided N at a constant 120 mg•liter^{-1}. This difference diminished during step 3, when both of these treatments were receiving N at 120 mg•liter^{-1} (data not presented). Therefore, there was little difference between the mean leachate N concentrations for these two treatments (Table 4). However, the solution with N at 175 mg•liter^{-1} produced leachate that was 2.5 and 3.5 times higher in NO_3-N concentration than that with N at 120 mg•liter^{-1} during trials 1 and 2, respectively.

The step solution with N at 60–90–120 mg•liter^{-1} was not adequate to obtain the yield potential of 'Midal' sweet pepper under the conditions of these trials. Peppers grown with N at 120 mg•liter^{-1} did not differ in early yield from those provided with N at 175 mg•liter^{-1}, and the higher N concentration promoted significantly higher final yield, but only in trial 2. Increased N did not affect the occurrence of BER in 'Midal' peppers. However, when peppers were grown with N at 175 vs. 120 mg•liter^{-1}, nutrient solution use increased by 10% and 40% and NO_3-N concentration in leachate increased 2.5- and 3.5-fold in trials 1 and 2, respectively, thereby increasing the potential environmental hazard. During these experiments, Petitt et al. (1994) also found that increasing solution-N concentrations for peppers from 120 to 175 mg•liter^{-1} promoted significantly higher population growth rates for green peach aphids (*Myzus persicae* Sulzer) feeding on those peppers. Growers should consider all these factors when making decisions concerning optimal N concentrations for greenhouse pepper production.

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