Pretransplant Watermelon Nutrition with Various Nitrate : Ammonium Ratios and Supplemental Calcium

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Abstract. Watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai 'Crimson Sweet'] was seeded in a commercial peat medium in multicell containers. Five NO₃: NH₄ ratios and five levels of supplemental Ca were combined factorially in a 100N-31P-265K mg-liter⁻¹ pretransplant nutrition regime. The medium was amended with CaCO₃ in 1989; the medium was not amended in 1990. Dry-matter accumulation had decreased with increasing NH₄-N 3 weeks after seeding both years. In 1989, increasing NH₄-N also had decreased seedling growth by the last sampling date due to decreased NH₄ uptake. Shoot N concentration was higher in 1990 than 1989, but N uptake was similar. On the first sampling date in both years, increasing the Ca concentration decreased seedling growth and increased medium electrical conductivity (EC). In 1990, increasing the Ca concentration raised shoot N concentration but did not increase seedling growth or N uptake. Either N form at 100 mg N/liter and Ca at 4 to 8 mmol-liter⁻¹ were optimal for watermelon transplant production, but Ca at >8 mmol-liter⁻¹ suppressed transplant growth.

Pretransplant nutritional conditioning (PNC) has been shown to influence transplant quality, seedling establishment, and yield for some crops (Adler et al., 1984; Dufault, 1985, 1986; Tremblay and Gosselin, 1989a, 1989b; Weston and Zandstra, 1989). Several studies have shown the importance of N rate in the PNC regime (Adler et al., 1984; Dufault, 1985, 1986), but N form in the regime has received less attention (Tremblay and Gosselin, 1989a, 1989b).

Ammonium-N as the predominant N source in fertilization regimes can be detrimental (Alan, 1989). Ammonium acidifies rhizospheric pH and depresses the uptake of other important cations (Alan, 1989; Barker and Maynard, 1972). Ammonium toxicity is ameliorated in media with a high pH-buffer capacity near pH 7.0 (Barker et al., 1966a, 1966b). Adding Ca to NH₄-N-based fertilizers decreases NH₃ volatilization (Fenn and Matocha, 1981; Fenn and Taylor, 1981), alleviates NH₄-N toxicity symptoms, and produces a synergistic plant growth response in calcareous and noncalcareous media (Fenn et al., 1987).

Recommended N sources for soilless media and hydroponic production contain NO₃-N (Lorenz and Maynard, 1980). Since typical

commercial soilless media are pH-buffered (Bunt, 1976) results with NH₄-N should be comparable to those with NO₃-N for transplant production, especially with Ca addition.

The objective of this experiment was to test the effects of various pretransplant NO₃: NH₄ ratios and supplemental Ca on the growth and N content of greenhouse-grown watermelon transplants.

'Crimson Sweet' watermelon was seeded in multicell containers (72 cells/container, 161 cells/m², 40 cm³/cell; TLC Polyform, Ply-

mouth, Minn.) using Fisons Sunshine Mix #3 (76% sphagnum peat, 24% fine vermiculite, dolomitic limestone, light nutrient charge, wetting agent; Fisons Western, Downers Grove, Ill.) on 17 July 1989 and 16 Apr. 1990. After being leached with tap water [3N-1P-7K (mg-liter⁻¹), pH 7.8, electrical conductivity (EC) 0.3 dS·m⁻¹], the medium contained low nutrient levels [6N-1P-7K(mg-liter⁻¹), pH 7.8, EC 0.37 dS·m⁻¹]. In 1989 only, CaCO₃ was added to the medium at 10% (w/v). Treatments consisted of 100N-31P-265K (mg-liter⁻¹) solutions having one of five NO₃: NH₄ ratios (100:0, 75:25, 50:50, 25:75, or 0:100) and one of five levels of supplemental Ca (0, 4, 8, 12, or 16 mM from CaCl₂) in factorial combination. Concentrations of N, P (from H₃PO₄), and K (from KCl) remained constant for all treatments. Solutions were prepared using tap water; its N content (NO₃-N) was not figured into the calculations. Treatment solution pH ranged from 6.1 (100 mg NH₄-N/liter) to 6.4 (100 mg NO₃-N/liter). Treatments were applied to runoff 6 days-week⁻¹ and began 1 week after seeding. Three weeks after seeding, treatment frequency was reduced to once every other day. Treatment application frequency was reduced in the last week to simulate the commercial practice of reducing fertilizer application to harden seedlings before transplanting. In 1989, the medium was leached with tap water between application days during the last week to reduce seedling growth. Daily canopy temperature in the double-polyethylene-covered greenhouse at Hermiston, Ore., averaged 35C in 1989 and 25C in 1990.

The experiment was designed as a randomized complete block with four replications of one 72-cell tray per replicate. Samples consisted of eight plants taken from each 72-cell

Table 1. Nitrate : ammonium ratio effect on shoot dry weight, leaf area, plant height, and shoot N content of watermelon seedlings. The growing medium was supplemented with CaCO₃ at 10% (w/v) in 1989 only.

	Dry wt ^a (g)		Leaf area ^a (cm ²)			N	
NO ₃ : NH ₄	Time after seeding (weeks)				Plant ht ^y (cm)	Concn (% dry wt)	Uptake (mg)
ratio	3	4	3	4			
1989							
100:0	2.69	5.47	372	517	14.6	1.64	90
75:25	2.63	4.96	360	470	14.5	1.65	82
50:50	2.61	4.91	373	465	14.5	1.53	75
25:75	2.55	5.12	371	491	14.6	1.64	84
0:100	2.51	4.72	339	464	14.6	1.54	73
Contrasts							
100:0 vs. others	***	***	NS	*	NS	NS	**
>50:50 vs. others	***	**	NS	NS	NS	*	**
<50:50 vs. others	***	NS	NS	NS	NS	NS	NS
0:100 vs. others	***	**	**	NS	NS	NS	**
1990							
100:0	2.10	3.92	182	324	12.3	2.24	87
75:25	2.05	3.94	180	314	11.9	2.08	82
50:50	2.00	3.93	180	321	11.9	2.16	85
25:75	1.92	3.82	183	320	11.3	2.24	86
0:100	1.81	3.83	182	357	12.1	2.36	90
Contrasts							
100:0 vs. others	***	NS	NS	NS	***	NS	NS
>50:50 vs. others	***	NS	NS	*	***	***	NS
<50:50 vs. others	***	NS	NS	**	***	***	*
0:100 vs. others	***	NS	NS	***	***	***	**

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^aMean of 20 eight-plant samples.

^bMean of 160 plants.

NS, *, **, ***Nonsignificant or significant at $P = 0.05, 0.01$, or 0.001 , respectively.

Table 2. Nitrate : ammonium ratio effect on medium solution EC and pH 3 weeks after seeding.

NO ₃ : NH ₄ ratio	1989		1990	
	EC	pH	EC	pH
100:0	0.88*	8.08	2.20	7.18
75:25	0.92	7.92	2.45	6.70
50:50	1.01	7.85	2.75	6.36
25:75	1.02	7.70	3.25	6.17
0:100	1.12	7.67	3.26	6.05
N × Ca	NS	NS	NS	***
100:0 vs. others	NS	***	***	***
>50:50 vs. others	*	***	***	***
<50:50 vs. others	*	***	***	***
0:100 vs. others	*	***	***	***

*Mean of 20 eight-plug samples.

ns,*,***Nonsignificant or significant at $P = 0.05$ or 0.001 , respectively.

tray replicate. Statistical Analysis System (SAS) PROC GLM was used to separate treatment effects using single-degree-of-freedom orthogonal contrasts for the NO₃ : NH₄ ratio main effect (SAS Inst., Cary, N.C.). Linear, quadratic, and cubic contrasts were used to analyze Ca main effect.

Medium pH and EC were determined 21 days after seeding. Medium extracts for measuring pH and EC were prepared using the saturated media extraction method of Warnke (1986). Plant dry weight and leaf area were measured 21 and 28 days after seeding. Leaves were removed from petioles before measuring area (LI-COR 3000; LI-COR, Lincoln, Neb.). Seedlings were excised at soil level, and plant height was measured at 28 days. Plant samples were dried in a forced-air oven at 65°C for 24 h and ground in a Wiley mill to pass through a screen with 0.425-mm pores (Lockman, 1980). Total N was determined by acid digestion of 0.4-g subsamples. Diluted digests were analyzed using an Alpkem rapid-flow analyzer at the Oregon State Univ. Plant Analysis Laboratory, Corvallis (Gaines and Mitchell, 1979).

NO₃ : NO₃ ratio. In 1989, shoot dry weights decreased with decreasing NO₃ : NH₄ ratio at 3 and 4 weeks after seeding (Table 1). Leaf area was reduced with 100% NH₄-N at 3 weeks; 100% NO₃-N produced the largest leaf area at 4 weeks. Plant height was not affected by the ratio. Shoot N accumulation was highest with NO₃-N as the predominant N form.

In 1990, shoot dry weights decreased with decreasing NO₃ : NH₄ ratio at 3 weeks; however, at 4 weeks shoot dry weight was not affected. Leaf area was similar for all N-form ratios at week 3, but increased as the NH₄-N proportion increased from 25% to 100% at week 4. Seedlings grew tallest with either 100% NO₃-N or 100% NH₄-N. Nitrogen concentration and accumulation were highest with 75% to 100% NH₄-N.

In 1989, seedling shoot dry weight was higher, leaf area was larger, and plants were taller than in 1990. Nitrogen accumulation was similar each year, but N concentration was <2% for all treatments in 1989, thus indicating a possible N deficiency. Reduced shoot N content with increasing NH₄-N in 1989 may have been induced by loss of available NH₄⁺, a decrease in NH₄⁺ uptake, or reduced transport of assimilated or free NH₄⁺ to the

shoots. Daily greenhouse maxima ranged from 29.5 to 43°C in 1989 and from 23.5 to 27°C in 1990. Higher temperatures may explain why plants grew larger in 1989 than in 1990. A 10°C increase in temperature may raise rates of ion uptake, respiration, and enzymatic reactions by more than a factor of 2 (Marschner, 1986). The increased growth may have diluted the N concentration, since tissue N concentration was lower in 1989.

In both years, medium EC increased with increasing proportion of NH₄-N at 3 weeks after seeding (Table 2). As medium EC increased, shoot dry weight decreased with more NH₄-N in the NO₃ : NH₄ ratio. Although medium EC was not measured later than week 3, we assumed that EC decreased over all treatments as frequency of applications decreased, and trays were leached after week 3 in 1989. Watermelon is moderately sensitive to increasing soil salinity, and growth decreased at a saturated extract EC >1.5 dS·m⁻¹ (Maas, 1986). In 1989, medium EC did not exceed 1.20 dS·m⁻¹. However, high temperatures in 1989 may have increased transpiration, which can cause solute accumulation in the rhizosphere (Marschner, 1986). Water potential in the rhizosphere could have decreased due to increased osmotic potential, thus reducing plant growth. EC measurements on medium solution extracts from the entire medium volume and not on the rhizosphere solution may not accurately reflect rhizosphere salinity. Medium EC was lower in 1989 than 1990, possibly due to increased ion uptake associated with greater dry matter accumulation.

Medium solution pH decreased in both years with increasing NH₄-N (Table 2). Hydrogen ion extrusion into the soil solution caused by NH₄⁺ uptake decreases medium pH (Barker et al., 1966a, 1966b). Also, NH₄⁺ may have depressed medium pH by displacing H⁺ on the medium cation exchange complex (Bunt, 1976).

High temperatures and high soil solution pH are conducive to ammonia volatilization from NH₄-N-based fertilizers (Fenn and Kissel, 1973, 1974). Barker et al. (1966b) reported a

lower N content in bean (*Phaseolus vulgaris* L.) leaves with NH₄-N fertilization, which increased root environment pH from 4.5 to 8.5. This alkalinity decreased free NH₄⁺, amide, and amino acid N fractions in bean leaves, but not in roots. In our study, pH decreased with increasing NH₄-N, the effect of N form on N accumulation most likely was attributable to excess soluble salts (EC) with NH₄ fertilization rather than to a pH effect.

Adding CaCO₃ to the medium raised extract pH in 1989 higher than in 1990.

Nitrogen application rate was ≈ 33% of the amount recommended in Hoagland's solution 1 and 2 (Lorenz and Maynard, 1980). Although N rate was reduced, higher greenhouse temperatures induced excessive shoot growth in 1989. In 1990, plant growth was slower, and N was not deficient. Based on these results, NO₃-N or NH₄-N at 100 mg·liter⁻¹ is adequate for watermelon transplant production. Transplant size is an important consideration for the transplant nursery and the grower. Large transplants are difficult to handle and may be seriously damaged during mechanical transplanting. Excessive N in the PNC could produce large, unwieldy transplants and increase N content of wastewater.

Similar seedling growth resulted with either form of N at 100 mg N/liter. No detrimental effects usually associated with NH₄-N were evident in either year. Our results concur with the findings of Barker and Maynard (1972) and Kirkby (1968) that growth with NH₄-N was slightly lower than, or similar to, that with NO₃-N in a medium buffered near pH 7.0.

The interaction between supplemental Ca (from CaCl₂) and NH₄-N on shoot N content and growth was not significant in 1989; therefore, CaCO₃ was not added to the medium in 1990. The CaCO₃ amendment may have resulted in solubilized Ca levels in the medium above the maximum Ca level of 10 mmol·liter⁻¹ reported by Fenn et al. (1987) for synergistic plant growth response with NH₄-N.

Supplemental Ca. Adding Ca to the PNC regimes affected seedling growth more in 1990

Table 3. Supplemental Ca effect on shoot dry weight, leaf area, stem length, and shoot N content of watermelon seedlings. The growing medium was supplemented with CaCO₃ at 10% (w/v) in 1989 only.

Ca (mm)	Dry wt ^a (g)		Leaf area ^a (cm ²)		Plant ht ^b (cm)	N	
	Time after seeding (weeks)					Concn	Uptake
	3	4	3	4		(% dry wt)	(mg)
1989							
0	2.61	5.05	378	479	14.6	1.56	79
4	2.54	5.01	366	474	14.6	1.60	80
8	2.56	4.95	365	475	14.6	1.63	81
12	2.50	5.02	353	476	14.6	1.62	81
16	2.47	5.16	351	492	14.6	1.60	83
	L*	NS	L*	NS	NS	NS	NS
1990							
0	1.98	3.90	183	328	12.2	2.14	83
4	2.00	4.11	182	333	12.3	2.15	88
8	2.05	3.95	191	334	12.0	2.24	88
12	1.98	3.81	179	322	11.8	2.25	86
16	1.88	3.68	172	319	12.2	2.30	84
	Q**	L***	L**	NS	C***	L***	Q*

^aMean of 20 eight-plant samples.

^bMean of 160 plants.

ns,*,**,*Nonsignificant or significant at $P = 0.05, 0.01, \text{ or } 0.001$, respectively. L, linear; Q, quadratic; C, cubic.

Table 4. Supplemental Ca effect on medium solution EC and pH 3 weeks after seeding.

Ca (mm)	1989		1990	
	EC	pH	EC	pH
0	0.70	8.06	1.40	6.77
4	0.79	7.96	1.94	6.59
8	1.03	7.76	2.76	6.45
12	1.25	7.71	3.46	6.36
16	1.18	7.73	4.35	6.30
	C*	Q***	L*	***
N x Ca	NS	NS	NS	***

*Mean of 20 eight-plug samples.

ns,***Nonsignificant or significant at $P = 0.05$ or 0.001 , respectively. L, linear; Q, quadratic; C, cubic.

than in 1989 (Table 3). In 1989, at week 3, shoot dry weight and leaf area decreased linearly with increasing Ca. Leaching the medium 3 weeks after seeding may have negated any response to increased Ca at week 4. Differences in dry weight in 1989 may have been enhanced with higher Ca levels from the CaCO_3 amendment. Fenn et al. (1987) measured 5 mmol Ca/liter solubilized by NH_4 uptake in a quartz sand amended with CaCO_3 at 1% (w/w).

In 1990, dry weight responded quadratically and leaf area decreased linearly. Shoot dry weight was highest and leaf area largest with Ca at 4 mmol-liter⁻¹, while plant height responded nonlinearly with increasing Ca. The shortest plants were obtained with 12 mmol Ca/liter.

Increasing Ca did not affect shoot N concentration and accumulation in 1989. However, in 1990, shoot N concentration increased linearly with increasing Ca. Shoot dry weight production per milligram of N decreased as Ca level increased. As Ca rate increased, less shoot dry matter was produced; N uptake, however, did not decrease at the same rate. This affected N concentration.

In both years at week 3, as Ca increased, medium EC increased (Table 4). Medium EC may have decreased 4 weeks after seeding due to medium leaching in 1989 and reduced treatment application frequency after week 3 in both years, producing variable growth from week 3 to 4 (Table 3). In 1989, as Ca level increased, medium pH decreased. In 1990, N form and Ca interacted to affect medium pH (Table 5). Within each Ca level, pH decreased as the NO_3 : NH_4 ratio decreased. Within each NO_3 : NH_4 ratio, increasing levels of Ca also decreased medium pH. However, at NO_3 : NH_4 ratios >50:50, the decrease was quadratic; at ≤50:50, the effect was linear. Ammonium-N uptake acidifies rhizosphere pH, while NO_3 -N increases rhizosphere pH (Alan, 1989; Barker

Table 5. Medium pH as affected by interaction of supplemental Ca and NO_3 : NH_4 ratio, 1990.

Ca (mm)	NO_3 : NH_4 ratio				
	100:0	75:25	50:50	25:75	0:100
0	7.65	6.96	6.61	6.34	6.27
4	7.32	6.78	6.47	6.30	6.11
8	7.08	6.66	6.32	6.14	6.05
12	6.96	6.59	6.22	6.09	5.93
16	6.89	6.53	6.18	6.00	5.92
	Q**	Q***	L***	L***	L***

***Significant at $P = 0.01$ or 0.001 , respectively. L, linear; Q, quadratic.

and Maynard, 1972). Cations displace H^+ on the peat exchange complex, thus decreasing rhizosphere pH (Bunt, 1976). Calcium and NH_4 -N together decreased medium pH. Nitrate uptake (OH^- extrusion) buffered acidity at pH values above those of treatments with NH_4 -N as the predominant N form.

The synergistic effect of supplemental Ca on NH_4 -N nutrition as reported by Fenn et al. (1987) was not detected in our study.

Increasing Ca influenced watermelon seedling growth by increasing medium solution EC. In this study, Ca at 4 to 8 mmol-liter⁻¹ was optimal for transplant production based on shoot growth and shoot N content. However, Ca at 12 to 16 mmol-liter⁻¹ suppressed seedling growth without adversely affecting N uptake. Based on these results, either NO_3 -N or NH_4 -N at 100 mg N/liter is recommended for watermelon transplant production.

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