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Nitrogen, Phosphorus, and Potassium Fertility Regimes Affect Tomato Transplant Growth

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Abstract. **Tomato (*Lycopersicon esculentum* Mill.) seedlings were nutritionally conditioned with solutions containing factorial combinations of N at 25,75, and 225 mg·liter^{-1}, P at 5, 15, and 45 mg·liter^{-1}, and K at 25, 75, and 225 mg·liter^{-1} to determine the effect of nutritional regimes on tomato transplant growth and quality. As N increased from 25 to 225 mg·liter^{-1}, fresh shoot weight, plant height, stem diameter, leaf number, leaf area, shoot and root dry weights, and total chlorophyll increased. Nitrogen accounted for the major source of variation. Phosphorus effects were significant only in 1988; Pat 45 mg·liter^{-1} increased fresh shoot weight, plant height, stem diameter, leaf number, and leaf area in comparison to 5 and 15 mg·liter^{-1}. Potassium did not significantly influence any of the growth variables measured in the study. For quality transplant production, nutrient solutions should contain at least N at 225 mg·liter^{-1}, P at 45 mg·liter^{-1}, and K at 25 mg·liter^{-1}.**

Tomato seedlings are used to establish tomato fields in many areas, including coastal South Carolina. Seedlings may be grown using very low rates of N, P, and -K, and the plants are usually hardened by withdrawing nutrients 7 to 10 days before shipping (J. Carson, personal communication). Upon arrival, the seedlings often appear chlorotic and "leggy". After transplanting, plant growth may stagnate for an extended period.

Seedling nutrition research is readily available on many vegetable crops. Generally, higher N–P–K regimes were associated with more vigorous seedling growth. Changing N rates from 10 to 250 mg·liter^{-1} and P rates from 5 to 25 mg·liter^{-1} increased shoot and root growth of 27-day-old muskmelon seedlings; also, increasing K rates from 10 to 250 mg·liter^{-1} increased muskmelon shoot growth (Dufault, 1986). Weston and Zandstra (1989) reported that N at 400 mg·liter^{-1} and P at 30 mg·liter^{-1} increased tomato seedling size. Asparagus seedling shoot and root weights increased as N was increased from 100 to 200 mg·liter^{-1} with P at 20 mg·liter^{-1} (Adler et al., 1984). Also, 350 mg N/liter enhanced broccoli, lettuce, pepper, and celery seedling growth, but root growth decreased, and increasing P from 5 to 125 mg·liter^{-1} increased shoot growth without significantly changing root growth (Tremblay et al., 1987). Potassium rates of 200 mg·liter^{-1} produced higher broccoli and pepper shoot dry weights than 50 or 300 mg K/liter (Tremblay et al., 1987).

During seedling production, it is necessary to supply adequate N, P, and K; however, nutrient needs differ among crops. Although some work has been done with tomatoes, the exact nutritional needs for the production of a quality seedling for the 'Sunny' tomato remain undefined. This cultivar is the major one in South Carolina and also is grown in other parts of the southeastern United States. Therefore, the objective of this study was to determine the effects of various rates of N, P, and K on 'Sunny' tomato seedling growth and transplant quality.

'Sunny' tomato seeds were planted in plastic nine-cell inverted-trapezoid containers (4 × 4 cm on top, 3 × 3 cm on bottom, 5.4 cm deep) with a 65-cm^3 cell volume filled with Sogemix No. 3, a peat and perlite medium (Sogevex, Pointelabel, Quebec, Canada), on 30 Dec. 1987 and 1988. Soil tests indicated that the medium contained (mg·liter^{-1}) 8N-28P–103K and had a pH of 5.7. Nutrient solutions consisted of factorial combinations of N from calcium nitrate at 25, 75, and 225 mg·liter^{-1}; P from calcium phosphate at 5, 15, and 45 mg·liter^{-1}; and K from potassium sulfate at 25, 75, and 225 mg·liter^{-1}. Additionally, magnesium sulfate was supplied at 70 mg·liter^{-1} and calcium carbonate was added to adjust each treatment to 347 mg Ca/liter to prevent a calcium confounding effect. Micronutrients were supplemented in the nutrient solutions at the recommended rate of 313 mg·liter^{-1} by using STEM (Soluble Trace Element Mix, Peter's Fertilizer Products, W.P. Grace & Co., Allentown, Pa.). A tap water control was also included. The pH of the nutrient solutions was adjusted to ≈ 7.0 using H_2SO_4 or NaOH, as needed. The flats were placed in the greenhouse where average day and night temperatures were 26C and 18C, respectively. In both years, each treatment plot consisted of nine plants. The 27 treatments were replicated four times and arranged in a randomized complete-block design.

Nutrients were first applied on 20 Jan. 1988 at the second true-leaf stage and 11 Jan. 1989 at the first true-leaf stage. In the first year, the cell packs were floated in nutrient solutions on a 22.9-cm-diameter plastic plate for 1 h to ensure saturation. In the 2nd year, the ceil packs were floated in 38 x 25 x 9-cm plastic storage boxes (Max Klein Co., Baraboo, Wis.) for 1 h. Then, in both years, the cell packs were allowed to drain for 1 h and returned to their respective bench locations. Nutrient solutions were applied three times per week until plants in at least one treatment across all replications were ≈ 15 to 20 cm high, with an adequately developed root system. Plants were overhead-irrigated with tap water [pH 7.1, $0NO_3$-$0.3PO_4$-P-1.3K (mg·liter^{-1}), electrical conductivity 0.15 mmhos/cm] as needed between nutrient applications. In 1988, the study was terminated on 8 Feb., 40 days after seeding, and on 26 Jan. in 1989, 29 days after seeding.

At experiment termination, the following growth variables were measured: shoot fresh weight per seedling; stem diameter (at cotyledon node); expanded true leaf number (leaves with clearly visible petioles); leaf area per seedling, including petiole, with a LI-COR LI-3100 leaf area meter (LI-COR, Lincoln, Neb.); and shoot and washed root dry weights after drying for 24 h at 65C. Leaf disks (0.31 cm^2) from the second true leaf tip of five randomly selected plants per treatment were removed with a hole punch and composite and total chlorophyll was determined (Moran, 1982). Growth data were analyzed using analysis of variance (ANOVA). The relative importance of N, P, and K on tomato seedling growth was determined by partitioning the total sum of squares for treatments into main and interaction effects and expressing the individual contribution to variation as a percentage of the sum of squares for the model (composed of only those sources of variation in the ANOVA).

Nitrogen was the major factor affecting tomato seedling growth in both years. Nitrogen accounted for the major portion of variation in plant height, stem diameter, leaf number, leaf area, total chlorophyll, fresh shoot weight, and dry shoot and root weights during both years (Table 1).

Generally, as N rate increased, root and shoot growth increased during both years. As N rate increased from 25 to 225 mg·liter^{-1}, plant height, stem diameter, leaf number, leaf area, total chlorophyll, and shoot fresh and dry weights increased (Table 1). Similar results were found with muskmelon by increasing N from 10 to 250 mg·liter^{-1} (Dufault, 1986). Root dry weight in 1988 increased with N from 25 to 225 mg·liter^{-1}; however, in 1989, root dry weight increased with N from 25 to 75 mg·liter^{-1}, but decreased at 225 mg·liter^{-1}. Even at the moderate to high

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Table 1. Effect of N-P-K fertility on tomato seedling characteristics and percentages of sum of squares partitioned into main and interaction effects (1988 and 1989).

Nutrient and concn ($mg\cdot liter^{-1}$)	Plant ht (cm)		Stem diam (mm)		Shoot wt (g) Fresh		Shoot wt (g) Dry		Root dry wt (mg)		Leaf no.		Leaf area (cm^2)		Total chlorophyll ($\mu g\cdot cm^{-2}$)	
	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989
N																
25	8.1 c[z]	8.1 c	2.5 c	2.3 c	1.25 c[z]	1.35 c	0.17 c	0.16 c	51 c	47 c	3.9 c[z]	3.3 c	29 c	36 c	89 c	85 c
75	12.0 b	10.4 b	3.3 b	2.9 b	2.60 b	2.40 b	0.32 b	0.24 b	75 b	54 a	4.8 b	4.0 b	65 b	72 b	103 b	102 b
225	15.8 a	11.5 a	4.2 a	3.3 a	4.77 a	3.21 a	0.49 a	0.28 a	89 a	50 b	5.7 a	4.5 a	129 a	105 a	130 a	117 a
P																
5	11.9 b	9.9 a	3.3 b	2.8 a	2.79 b	2.30 a	0.32 a	0.23 a	71 a	50 a	4.7 b	3.9 a	72 b	69 a	109 a	99 a
15	11.6 b	10.1 a	3.2 b	2.9 a	2.78 b	2.33 a	0.32 a	0.23 a	73 a	50 a	4.7 b	3.9 a	72 b	73 a	112 a	103 a
45	12.5 a	9.9 a	3.4 a	2.8 a	3.05 a	2.33 a	0.33 a	0.23 a	71 a	50 a	4.9 a	3.9 a	79 a	71 a	102 b	100 a
Source of variation[y]																
Rep	2.31**	0.88	0.73**	2.94**	1.16**	1.47**	3.04**	2.95**	2.02**	36.54**	5.86**	1.22*	1.20**	3.21**	2.51**	0.91
N	86.40**	80.20**	95.65**	84.26**	95.08**	87.10**	91.60**	71.99**	85.89**	17.31**	87.09**	86.62**	95.78**	81.76**	78.40**	65.40**
P	1.02**	0.27	0.64**	0.05	0.71**	0.04	0.28	0.07	0.40	0.00	0.67**	0.00	0.60**	0.21	4.42**	0.79
K	0.15	0.47	0.02	0.45	0.01	0.28	0.01	0.76	0.40	0.00	0.01	0.47	0.00	0.29	0.25	1.74
NP	0.46	0.29	0.40**	0.10	0.66**	0.15	0.20	0.42	0.40	1.92	1.01**	0.54	0.87**	0.56	2.14**	1.18
NK	0.13	0.99	0.09	0.65	0.08	0.60	0.09	1.01	0.81	1.92	0.18	0.54	0.02	0.70	0.46	1.31
PK	0.16	0.69	0.05	0.45	0.05	0.47	0.24	1.35	0.40	1.92	0.34	0.50	0.06	0.18	0.61	0.58
NPK	0.48	0.95	0.13	0.80	0.04	0.68	0.28	2.67	0.00	1.92	0.42	0.97	0.05	0.57	1.51	2.69
Error	8.89	15.26	2.28	10.31	2.21	9.21	4.26	18.78	9.68	38.46	4.42	9.15	1.40	12.52	9.70	25.40

[z]Mean separation within main effect by least significant difference at $P = 0.05$.

[y]Composed of all sources of variation.

*,**F value significant at $P = 0.05$. or 0.10, respectively. Values not followed by asterisks are not significant at $P = 0.05$.

N levels, growth did not seem to "plateau" off, except for root dry weight. Yet, higher levels might additionally increase growth. Weston and Zandstra (1989) reported that N as high as 400 $mg\cdot liter^{-1}$ increased 'Pik-Red' tomato seedling growth.

The main effects of P were significant only in 1988 on some of the variables measured (Table 1). Although significant, the contributions of P to variation were minor compared to N effects. Phosphorus accounted for only a small percentage of the total variation in plant height, stem diameter, leaf number, leaf area, total chlorophyll, and fresh shoot weight. There was no significant difference between the 5 and 15 mg P/liter treatments, but increasing the P rate to 45 $mg\cdot liter^{-1}$ increased plant height, stem diameter, leaf number, leaf area, and fresh shoot weight. This result is comparable to Weston and Zandstra's (1989) results in which 30 mg P/liter increased seedling growth. Higher P rates may increase growth more than the levels reported in our study. The higher rate of P significantly decreased total chlorophyll content in 1988, but not in 1989. Dry shoot and root weights were not significantly influenced by P rates in 1988. Phosphorus may not have significantly affected any of the variables in 1989 because the plants were harvested 11, days earlier than in 1988, so that there was less time for P to affect growth.

Potassium did not significantly influence any of the growth variables measured in this study (Table 1).

Interactions between N and P were only significant in 1988 for stem diameter, leaf number and area, total chlorophyll, and fresh shoot weight (Table 1). In comparison to the total sum of squares attributable to N, the interaction effects were very small and negligible.

Understanding the importance of N, P, and K on tomato seedling growth should provide new insight into the production of tomato seedlings. In previous work on muskmelon (Dufault, 1986), seedling growth was enhanced with 250 mg N/liter. Our results indicated that 'Sunny' tomatoes are similar in their nutritional needs for. seedling growth. Weston and Zandstra (1989) increased seedling growth of 'Pik-Red' tomatoes with 400 mg N/liter and 30 mg P/liter. However, it may be that N rates as high as 350 to 400 $mg\cdot liter^{-1}$ promote excessive shoot growth.

We conclude that production of quality tomato seedlings requires nutrient solutions that contain at least 225 mg N/liter and 45 mg P/liter. While K did not significantly affect any of the seedling growth variables measured in this experiment, we recommend that at least 25 mg K/liter be supplied in nutrient solutions during seedling production to sustain growth at the levels reported.

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