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Nitrogen and Phosphorus Preconditioning of Small-plug Seedlings Influence Processing Tomato Productivity

Ronald W. Garton

Agriculture Canada, Research Station, Harrow, Ont. NOR 1G0, Canada

Irvin E. Widders

Department of Horticulture, Michigan State University, East Lansing, MI 48824-1112

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Abstract. Seedlings of processing tomato 'H 2653' (*Lycopersicon esculentum* Mill.) were cultured in 288-cell (< 6 cm³ volume) plug trays in a soilless growing medium. Pretransplant fertilization with nutrient solutions containing 10 or 20 mM N and 2 or 5 mM P for 10 days altered the total ammoniacal-N and P, and the soluble NO₃-N and PO₄-P concentrations in the shoot tissue at transplanting. Post-transplanting shoot and root growth were more rapid in late May plantings than in earlier plantings. The 20-mM N and 2-mM P pretransplant treatment caused the most rapid shoot growth following early season plantings in the field. Rapid seedling establishment after transplanting was generally not a good indicator of potential fruit yield. The 5-mM P pretransplant treatment produced higher marketable fruit yields in early plantings but not in later. Culture of seedlings under a low fertilization regime (5.4 mM N, 1.0 mM P, and 1.6 mM K) before pretransplant treatment produced as high or higher fruit yields than did seedlings from a higher regimen. Withholding fertilizer temporarily before transplanting resulted in a depletion in tissue N and P concentrations, slow post-transplanting shoot growth, and lower yields.

Vegetable seedlings cultured for transplanting in small-size plug cells require careful management (Dufault and Waters, 1985; Weston, 1988) due to the volume limitations of the cell (< 6 cm³) and the high seedling

densities within the tray (≈ 28 plants/100 cm²). Essential nutrient elements within the cell plug are frequently insufficient to sustain plant growth for an extended period. A proposed fertilization scheme (Widders, 1989) for culture of tomato seedlings involves application of moderately low-concentration nutrient solutions (e.g., 4.3 mM N, 0.8 mM P, and 1.3 mM K) throughout the first 3 to 5 weeks of growth, followed by treatment with high concentrations of N and P for 5 to 10 days before transplanting. This fertilization strategy has two distinct advantages for small

plug-cell seedling culture: 1) Vegetative growth of seedlings can be controlled by limiting initial supply of nutrients, thus reducing the potential for root binding or excessive stem elongation; 2) N and P content within the seedling tissue can be enhanced before transplanting, which is important for rapid plant establishment and nutrient uptake from the soil thereafter (Widders, 1989).

The objective of this study was to determine the influence of pretransplant fertilization with N and P of small plug-cell cultured processing tomato seedlings on field establishment and ultimate fruit yield. The effects of field environmental conditions, as determined by time of planting, on seedling response to the pretransplant treatments were also evaluated.

Field experiments were conducted at the Agriculture Canada Research Station at Harrow, Ont., during Summer 1986 and 1987 and at the Michigan State Univ. Horticulture Research Center, East Lansing, during 1987. The soil at Harrow was a Fox sandy loam (Brunisolic gray brown Luvisol Typic Hapludalf) with a pH of 6.4. Nitrogen (80 kg·ha⁻¹) was applied as ammonium nitrate to the field before planting. At East Lansing, the soil was a Spinks sandy loam (Psammic sandy, mixed, mesic, Hapludalfs) with a pH of 6.3 and a cation exchange capacity of 4. The soil was preplant fertilized with (kg·ha⁻¹) 80N-160P-160K.

In all three experiments, seeds of 'H 2653' (H.J. Heinz Co.) processing tomato were sown in 288-cell plug trays (TLC Polyform, Plymouth, Minn.) containing ASB medium (ASB Greenworld, Waterloo, Ont.), a peat-based variation of the Cornell mix. Individual cells were tapered with a volume of < 6 cm³ (2 × 2 × 2 cm length, width, depth). The seedlings were cultured in a greenhouse with no supplemental lighting.

At Harrow, seeds were sown on 1 and 16 Apr. 1986 and 24 Mar. and 16 Apr. 1987. Seedlings were fertilized three times weekly with soluble fertilizer (20N-8.6P-16.6K) at 0.3 g·liter⁻¹ (4.3N-0.8P-1.3K; mM). When the seedlings were 4 to 5 weeks old, ≈ 12 cm high, four pretransplant fertilization

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Table 1. Composition of nutrient solutions used to fertilize tomato seedlings during a 5- or 10-day pretransplant period.

Salts	Concn in treatment solutions (mM)			
	20 N 5 P	20 N 2 P	10 N 5 P	10 N 2 P
NaH ₂ PO ₄	3	2	3	2
NH ₄ H ₂ PO ₄	2	---	2	---
KNO ₃	4	4	4	4
Ca(NO ₃) ₂	2	2	2	2
MgSO ₄	1	1	1	1
NH ₄ NO ₃	5	6	---	1

treatments, factorial combinations of N at 10 or 20 mM and P at 2 or 5 mM (Table 1) were imposed. Solutions also contained K, Ca, Mg, S, and 'micronutrients (Table 1) and were acidified to a final pH of 6.0 using 1.0 N H₂SO₄. Pretransplant treatment solutions were applied twice daily for 5 or 10 days, followed by field planting on 12 and 28 May 1986 and on 13 and 28 May 1987. No starter solution was used at field planting. Plant spacing was 1.5 m between rows and 30 cm between plants within the row.

In the East Lansing study, seedlings were staggered, from 28 Mar. to 23 Apr., to com-

pensate for anticipated differences in growth due to fertilization treatments and to prepare plants for early and late transplanting times. Seedlings were fertilized daily from emergence to 10 days before transplanting with nutrient solutions containing either 5.4N-1.0P-1.6K (mM) or 10.8N-2.0P-3.2K (mM). Ten days before transplanting, the seedlings were subjected to pretransplant nutrient treatments (Table 1) including one in which nutrients were withheld. Field plantings were made on 12 and 28 May.

The experimental design in the field trial at Harrow in 1986 was a 2 × 2 × 2 factorial in a randomized complete block with four replications. The factors included pretransplant fertilization duration (5 or 10 days) and N and P concentrations. In 1987 at Harrow, fertilization duration was not included as a factor, and all nutrient treatments were applied for 10 days before transplanting. At East Lansing in 1987, a 2 × 5 factorial in a randomized complete-block design with three replications was used, with factors being fertilization regimes during seedling culture and pretransplant nutrient treatments. Individual plots consisted of a single row 25 m long, bordered by guard rows, from which

10 m (Harrow) or 5 m (East Lansing) were harvested for fruit yield determination. The remaining section of row was divided into 3-m units and separated by 1-m within-row guards that were randomly assigned specific times for sampling of shoots following transplanting.

For growth analysis, shoots were excised at the cotyledonary node from ten neighboring plants at transplanting and at frequent intervals during the first 4 weeks after transplanting. Fresh tissue was rinsed in deionized water and dried at 60C in a forced-air oven for 4 days. Individual plant shoot dry weights were measured. At East Lansing, seedlings were also excavated at 3 and 5 days after transplanting to evaluate root growth. After washing roots to remove soil, new roots that had grown from the soilless-medium plug and from the stem subsequent to transplanting were excised. Root length was determined by the root line-intersection method of Newman (1966).

The plots were once-over destructively harvested when ≈ 80% of the fruit had reached the red-ripe stage. Harvest dates for the early and late plantings were 15 and 28 Aug. (Harrow, 1986), 13 and 27 Aug. (Harrow, 1987), and 17 and 31 Aug. 1987 (East Lansing). Fresh weights of marketable, green, and cull fruit were recorded. Results of all experiments were tested using analysis of variance. Means were separated by least significant difference at *P* = 0.05 or 0.01.

Dried shoot tissue samples were ground to pass a 20-mesh screen in a Wiley mill and digested in concentrated H₂SO₄ before total ammoniacal-N analysis or in perchloric acid and hydrogen peroxide after the method of Adler and Wilcox (1985) for total P analysis. Soluble nitrate and PO₄-P were extracted from tissue samples in a 3% acetic acid solution (Chapman and Pratt, 1961). Total ammoniacal-N was determined by a Micro-Kjeldahl procedure (Lachat Quikchem Method 13-107-06-2-B; Lachat Instruments, 1986) using a Lachat ion analyzer (Lachat Instruments, Mequon, Wis.). Total P and soluble PO₄-P were determined calorimetrically by the ammonium molybdate-aminonaphthol sulfonic acid reduction method (Chapman and Pratt, 1961). Nitrate in extract solutions was analyzed calorimetrically, following reduction to nitrite using a copperized cadmium column, using again the Lachat ion analyzer after method no. 12-107-04-1-B (Lachat Instruments, 1986).

Nitrogen and phosphorus concentrations in shoot tissue of tomato seedlings at transplanting time were affected by pretransplant fertilization regimes in both the Harrow and East Lansing experiments. When seedlings were fertilized for 10 days with 20 mM N, the total ammoniacal-N and the soluble NO₃-N concentrations (4.04% and 1.33% dry weight, respectively) were significantly higher than in seedlings fertilized with 10 mM N (3.48% and 0.79% dry weight) (Table 2). High P concentrations (5 mM) in the fertilization solution also resulted in higher total P and soluble PO₄-P levels within shoot tissue (1.22% and 0.77% dry weight, respec-

Table 2. Influence of nutrient concentration during transplant culture and pretransplant treatment on shoot tissue concentrations of total ammoniacal-N, total P, NO₃-N, and PO₄-P at transplanting (East Lansing 1987).

Treatment (mM)	Tissue concn (% dry wt)			
	Total		NO ₃ -N	Soluble PO ₄ -P
	Ammoniacal N	P		
Seedling culture ^z				
10.8N-2.0P-3.2K	3.51	1.09	0.95	0.69
5.4N-1.0P-1.6K	3.25	0.95	0.75	0.60
F test	**	**	**	**
Pretransplant treatment ^y				
20 N, 5 P	4.13	1.15	1.33	0.74
20-N, 2 P	3.95	1.04	1.33	0.64
10 N, 5 P	3.40	1.29	0.77	0.80
10 N, 2 P	3.57	0.90	0.82	0.58
0 N, 0 P	1.84	0.72	---	0.45
LSD 0.01	0.48	0.13	0.36	0.11

^zEach value is an average of five pretransplant treatments × three replicates × two planting dates.

^yEach value is an average of two seedling culture treatments × three replicates.

---Concentration below the detectable limits of the analytical procedure.

**Significant at *P* < 0.01.

Table 3. Influence of pretransplant N and P fertilization regimes and time of transplanting on shoot growth of tomato seedlings at 28 days after transplanting and on final yield of marketable fruit (Harrow 1986).

Treatment	Shoot dry wt (g/10 plants)		Fruit yield (t·ha ⁻¹)	
	Transplanting date (May)			
	12	28	12	28
Nitrogen (mM) ^z				
20	20.3	70.7	42.4	42.9
10	18.6	75.0	43.1	44.7
F test	*	NS	NS	NS
Phosphorus (mM) ^y				
5	17.8	64.5	44.4	43.9
2	21.0	81.2	41.0	43.7
F test	*	*	*	NS
Transplanting date ^x	19.4	72.8	42.7	43.8
F test	**		NS	

^zEach value is an average of two P treatments × four replications.

^yEach value is an average of two N treatments × four replications.

^xEach value is an average of two N × two P treatments × four replications.

NS, *, **Nonsignificant or significant at *P* < 0.05 or 0.01 respectively.

Table 4. Influence of nutrient concentration during seedling culture and pretransplant treatment on shoot dry weight (14 days after transplanting), root length (5 days after transplanting), and fruit yield of processing tomatoes (12 May planting, East Lansing 1987).

Treatment	Shoot dry wt (g/10 plants)	Root length (cm/plant)	Fruit yield (t·ha ⁻¹)
Seedling culture (mm) ^z			
10.8N-2.0P-3.2K	4.2	25.7	59.4
5.4N-1.0P-1.6K	4.5	26.6	66.9
F test	NS	NS	*
Pretransplant treatment (mm) ^y			
20 N, 5 P	4.8	38.5	66.5
20 N, 2 P	5.1	33.3	66.2
10 N, 5 P	4.6	20.8	66.2
10 N, 2 P	4.5	31.6	64.5
0 N, 0 P	2.7	6.4	53.4
LSD 0.05	1.4	21.3	**

^zEach value is an average of five pretransplant treatments × three replicates.

^yEach value is an average of two seedling culture treatments × three replicates.

^zSingle degree of freedom orthogonal contrast between the 0 N, 0 P treatment, and other treatments.

NS, * Nonsignificant or significant at $P < 0.05$, respectively.

tively) as compared to fertilization with 2 mm P (0.97% and 0.61% dry weight). The high N and P pretransplant fertilization regimens also enhanced the tissue concentrations above those levels present in the tissue before the treatments (data not presented).

Withholding essential plant nutrients for 10 days before transplanting resulted in a rapid decline in the concentration of both total and soluble N and P fractions within the shoot (Table 2). Total ammoniacal-N concentration (1.18% dry weight) was ≈ 50% of the initial level (data not presented), while soluble NO₃-N was depleted to below the analytical detection limits. Accumulated nitrate in shoot tissue provides an important reserve of non-assimilated N that can be readily used to support future growth. Soluble NO₃-N concentrations in leaf tissue are correlated with relative growth rate of tomato plants (Gosselin et al., 1984).

Growth and development of tomato plants in the field were comparable to commercial plantings both years. Plant stands that ranged from 90% to 98% (Harrow 1986) and 82% to 90% (East Lansing) were not influenced by pretransplant fertilization. Since crop responses to the pretransplant treatments were similar for all experiments, select data from Harrow 1986 and East Lansing 1987 are presented for discussion.

Pretransplant N and P treatments did not consistently produce a post-transplanting growth response. In early season plantings (Harrow 1986, 1987), initial shoot growth was promoted by pretransplant fertilization with high N (20 mm) and low P (2 mm) concentrations (Table 3). In later plantings, when growth was more rapid due to more-favorable field temperatures, the growth response from low P but not from N was observed. No N and P pretransplant treatment effects on shoot growth were observed in the East Lansing experiment (Table 4). It is unclear why the 2 mm P treatment resulted in more-rapid vegetative growth than the 5 mm treatment under certain conditions. Gibson

and Pill (1983) also reported that when P supply to tomato plants was increased, a reduction in shoot growth rate and final plant dry weight occurred.

Shoot growth and new root elongation following field planting were significantly slowed by the withholding of nutrients before transplanting (Table 4). After 14 days in the field, shoots from these plants weighed ≈ 50% as much as those pretransplant fertilized. The net length of newly formed roots extending out from the plug at 5 days after the early transplanting date ranged from 21 to 38 cm for fertilized plants but only 7 cm for unfertilized plants. The magnitude of the response was similar for the later planting, even though the net amount of initial root growth was much larger, > 60 cm (data not presented).

Tomato fruit yield was affected by pretransplant P but not N fertilization in both the 1986 (Table 3) and 1987 (data not presented) experiments at Harrow. In the early May plantings, the 5-mm P pretransplant treatment produced significantly higher yields of marketable fruit than the 2-mm P treatment, even though vegetative shoot growth following transplanting was initially slower (Table 3). No yield response to P was observed in the late plantings.

In the East Lansing experiment, pretransplant treatment with N and P had no effect on final fruit yield (Table 4). The withholding of nutrients before transplanting, however, was observed to lower yields of marketable tomato fruit by ≈ 10 t·ha⁻¹ (Table 4). The magnitude of this yield response was greatest in the early season planting (data not presented for late planting). Low fruit productivity as a result of withholding nutrients from fresh market tomato seedlings was also demonstrated by Brasher (1941) and Weston and Zandstra (1986).

The culture of small-plug tomato seedlings under a relatively low fertilization regimen before pretransplant treatment was found to have no effect on either shoot or root growth (Table 4). Fruit yield, however, was as high

(late planting, data not presented) or higher (early planting) than from seedlings cultured under a higher fertilization regimen. This is an important result, since it suggests that growers could use initially lower elemental concentrations in the fertilization solution (e.g., 5.4N-1.0P-1.6K; mm) to avoid excessively rapid vegetative growth and oversizing of small-cell-grown seedlings before the desired time for transplanting. As long as the seedlings are pretransplant-treated with higher concentrations of N and P to adjust upward the mineral nutrient status of the seedlings, post-transplanting vegetative growth and fruit yield should not be compromised. Possibly, the low nutrient status of these seedlings even predisposes the root system to take up N and P more rapidly during the pretransplant treatment (Katz et al., 1986; Lee and Rudge, 1986).

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