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Effect of Root Container Size and Location of Production on Growth and Yield of Tomato Transplants

Leslie A. Weston and Bernard H. Zandstra
Department of Horticulture, Michigan State University, East Lansing, MI 48824

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Abstract. **'Pik-Red' tomato (*Lycopersicon esculentum* Mill.) transplants produced in 2 locations (Florida and Michigan), in 6 root cell sizes were compared for fruit productivity in Michigan. Transplants grown in large cells produced more early yields than those from small cells, but generally did not produce more total yields. Large root cell size had a greater effect on transplant size than did wide spacing in the flat. Speedling root cell size 175 (39.5 cm^3) produced the largest transplants, the largest early fruit yields, and the greatest weight of marketable fruit. Transplants grown in Speedling trays in Michigan produced larger early yields than Speedling transplants grown in Florida.**

Tomatoes are a major fresh market crop in Michigan. They are grown from transplants because of the relatively short growing season. Good-quality transplants are essential for successful tomato production in this system, since plant condition at transplanting affects stand, early yield, total yield, and fruit size (3, 6, 7, 9).

A number of cultural practices are known to affect tomato transplant quality and subsequent fruit yield in the field. Fruit yield increased as space per plant during seedling growth in the greenhouse increased (2, 6, 9, 12). Plants grown in large containers or root cells had more leaves, faster growth rate after transplanting (9, 12), and produced more early yield than plants from small containers (6, 11, 15). Seedlings adequately fertilized with N, P, and K produced greater early and total yields than seedlings fertilized with minimal amounts of these nutrients (4, 5, 10). Overhardening and poor or prolonged shipping and storage of transplants also reduced tomato yields (5, 14).

Michigan growers obtain a majority of their plants from the southern United States. Most of the plants are field-grown and often suffer severe transplant shock on field setting (5, 13, 14); therefore, farmers are looking for other sources of plants. Speedling (Sun City, Fla.), has become a major supplier of greenhouse-grown plants for Michigan farmers. The Speedling system uses trays of the same outer dimensions but with several available cell sizes. Plants grown in the small-size cells are less expensive to produce than those in large cells because they require less greenhouse space. The Speedling plants are normally of good quality, but often suffer a lag in growth after setting in the field. The size of the root cells and the conditions under which the transplants are produced may affect their growth and productivity in the field.

Since root cell size and environment of production are known to affect transplant quality, these studies were initiated to compare Michigan- and Florida-grown tomato plants for quality and productivity.

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Materials and Methods

Transplant production and growing conditions. At Michigan State Univ., 'Pik-Red' tomato seeds were germinated for 48 hr at 25°C and suspended in Viterra II hydrogel (1% by weight) before planting in a modified Cornell Mix A (8) in 5 sizes of flats (080, 100A, 125, 150, and 175) on 13 May 1980 and 4 May 1981 (Table 1). The plants were grown in a greenhouse with temperatures of 26° (day) and 20° (night), 13- to 14-hr photoperiod, and luminance of 500 $\mu mol \cdot s^{-1} \cdot m^{-2}$. No supplemental lighting was used. Plants were watered overhead twice daily. When true leaves appeared, the plants were fertilized weekly with a soluble 20N–8.6P–16.6K fertilizer at a rate of 2.7 g per liter of water (540 ppm N).

'Pik-Red' tomato seeds of the same lot were sown at Speedling facilities on 13 May 1980 in 080-, 100A-, and 125-size flats and on 4 May 1981 in 080-, 100A-, 125-, 150-, and 175-size flats. Plants were grown in a modified Cornell Mix A (8) in a plastic house with maximum 29°C (day) and minimum 16°

Table 1. Depth, area, and volume of root cells of Speedling planter flats.[z]

Flat size	Cell side length (cm)	Cell surface area (cm^2)	Cell depth (cm)	Cell volume (cm^3)
080	2.03	4.1	3.2	4.4
080A	2.03	4.1	4.1	5.6
100A	2.54	7.8	7.2	18.8
125	3.18	10.1	4.6	15.4
150	3.81	14.5	6.4	30.7
175	4.45	18.7	6.4	39.5

[z]Speedling (Todd) planter flats are made of expandable polystyrene and are produced in a number of sizes, with a descriptive number indicating the cell size, (e.g., a 100-size flat has cells 2.5 cm long on a side). The size numbers indicate this length in hundredths of an inch. The cells are shaped as square, inverted pyramids.

Table 2. The influence of root cell size and location of production on the size of tomato plants 28 days after sowing.

Plant source	Root cell size	Height[z] (cm)	Leaf area (cm^2)	Shoot dry wt (g)
Michigan	080	10.1 a	6.5 a	0.07 a
	080A	11.9 bc	7.9 a	0.09 ab
	100A	20.3 de	33.5 b	0.27 cd
	125	22.2 fg	45.8 e	0.30 de
	150	26.8 h	75.7 f	0.42 g
	175	20.9 def	70.5 f	0.44 g
Florida	080	13.1 c	5.5 a	0.08 ab
	080A	9.3 a	6.0 a	0.06 a
	100A	10.7 ab	7.4 a	0.12 b
	125	23.3 g	36.2 bc	0.24 c
	150	19.5 d	39.1 cd	0.32 e
	175	21.6 ef	41.8 de	0.37 f

[z]Height, leaf area, and shoot dry weight data are the means of 4 plants. Mean separation in columns by Duncan's multiple range test, 5% level.

Table 3. Influence of different size of root cells and location of transplant production on yield of 'Pik-Red' tomato plants grown at Sodus, Mich. in 1980.

Location	Flat size	Yield[zy] Early[x] ($t \cdot ha^{-1}$)	Total ($t \cdot ha^{-1}$)
Florida	080	0 a	48.32 a
	100A	0.51 ab	53.20 a
	125	1.12 ab	61.55 a
Michigan	080	1.83 abc	75.48 a
	100A	6.82 de	70.60 a
	125	2.64 cd	67.14 a
	150	4.07 cd	68.36 a
	175	13.12 e	65.92 a

[z]Yields are means of 3 replications. Early yields were harvested 14 and 22 Aug.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.
[x]A square-root transformation was performed on early yield data to maintain homogeneity of variances.

(night) temperatures. The plants were maintained under an average luminance of 600 $\mu mol \cdot s^{-1} \cdot m^{-2}$ with a 13- to 14-hr photoperiod. No supplemental lighting was used. Plants were watered overhead daily and fertilized with 30 ppm N at each watering, until one week before shipment when N was withheld. Tomato seedlings were removed from greenhouse flats and shipped by air in ventilated boxes to Michigan State Univ. Plants were stored <24 hr in boxes before arrival in Michigan.

In 1981, height, leaf area, and shoot dry weight of 4 plants from each cell size and each location were measured before transplanting. Leaf area was measured using an electronic leaf area meter (LI-COR, Model LI-3000).

Field experiments. Plants were transplanted into the field at the Sodus Horticultural Research Station (Michigan) on 11 June 1980. The roots were dipped in a 10N–22.4P–6.7K starter solution before transplanting. In 1981, tomato plants were transplanted into the field at the Horticulture Research Center (East Lansing, Mich.) on 28 May. Plant roots were dipped in a 20N–8.6P–16.6K starter fertilizer solution. The fields were sprinkler-irrigated after transplanting.

Preplant fertilizer was applied according to soil test recommendations to obtain 100 $kg \cdot ha^{-1}$ N, 65 $kg \cdot ha^{-1}$ P, and 250 $kg \cdot ha^{-1}$ K. The plants were sidedressed with 56 $kg \cdot ha^{-1}$ N after first fruit set. The plots were irrigated as needed during the growing seasons.

The field experiment was designed as a randomized complete block with 3 replications in 1980. There were 6 plants per plot, with 61 cm between plants and 122 cm between rows. In 1981, the field experiment was designed as a randomized complete block with 3 replications in a factorial arrangement of 6 cell sizes and 2 sources of plants. Each plot contained 14 plants with 61 cm between plants in rows and 122 cm between rows. Fruit showing red color were harvested weekly. In 1981, tomatoes were graded as large (>6.7 cm diameter), small (<6.7 cm diameter), and culls (1). Tomatoes harvested during the first 2 weeks comprised early yields.

Spacing study. Tomato seedlings were grown in 6 flats of each size used in the field studies and raised in the greenhouse at Michigan State Univ. as described previously. In 3 flats of each size, seeds were planted in adjacent cells in a square of 5 cells on a side. In the other 3 flats of each size, 25 seeds were planted so that the distance between seedlings was 8 cm × 8 cm regardless of cell size. Leaf area and shoot dry weight of 6 plants per treatment were measured 15 and 30 days after planting. The experiment was designed as a randomized complete block in a factorial arrangement of 6 cell sizes and 2 spacings, with each flat considered a replication.

Statistical analysis. Data were analyzed by analysis of variance. Where appropriate, Duncan's multiple range test was used for mean separation. Main effects in factorial experiments were separated by LSD (0.05). The relationship between root cell volume and early yields in the 1981 experiment was determined by regression analysis.

Results and Discussion

The heights of Michigan and Florida plants of the same root cell sizes were similar 28 days after sowing in 1981, but Michigan tomato plants generally had greater leaf area and shoot dry weight than Florida plants (Table 2).

In 1980, Michigan-grown 100A- and 175-size plants produced the greatest early tomato yield (Table 3). With the exception of 080 plants, Florida plants of all sizes produced less early yield than did Michigan plants of all sizes. Generally, as the volume of the root cells increased, early yields also in-

Table 4. The influence of root cell size and location of transplant production on early and total yields of 'Pik-Red' tomato plants in 1981.

Root cell size and location of production	Total early yield[z] ($t \cdot ha^{-1}$)	Early large fruit yield ($t \cdot ha^{-1}$)	Total fruit yield ($t \cdot ha^{-1}$)	Total large fruit yield ($t \cdot ha^{-1}$)
		Root cell size		
080	8.25	4.90	34.78	12.01
080A	7.53	3.00	36.89	10.73
100A	9.13	3.70	34.37	10.87
125	12.79	9.17	36.17	16.04
150	14.57	9.05	36.52	15.60
175	17.93	12.34	42.25	19.93
F	**	**	*	**
LSD (0.05)	4.38	3.62	7.10	4.28
		Location of transplant production		
Michigan	13.62	8.53	38.37	15.70
Florida	9.78	5.52	35.29	12.69
F	**	*	NS	NS
LSD (0.05)	2.53	2.09	---	---
Interaction				
Root cell size × location	NS	NS	NS	NS

[z]Yields are the means of 3 replications. Early yields were harvested during the first 2 weeks of the harvest season. Large fruit were >6.7 cm in diameter.
[NS,*,**]Nonsignificant (NS) or significant at the 5% (*) or 1% (**) levels.

Table 5. The influence of root cell size and spacing on the growth of 15- and 30-day-old 'Pik-Red' tomato seedlings.

	15 days		30 days	
Treatment	Leaf area[z] (cm^2)	Shoot dry weight (g)	Leaf area (cm^2)	Shoot dry wt (g)
		Root cell size		
080	1.9	0.024	30.4	0.097
080A	2.0	0.033	34.4	0.091
100A	4.3	0.052	55.7	0.128
125	4.7	0.063	52.9	0.161
150	5.4	0.064	59.0	0.175
175	6.2	0.073	67.2	0.170
F	**	**	**	**
LSD (0.05)	0.6	0.009	15.9	0.027
		Spacing in flat		
Normal	4.0	0.046	52.2	0.127
Wide	4.1	0.057	47.6	0.147
F	NS	**	NS	**
LSD (0.05)	---	0.006	---	0.010
Interaction				
Spacing × root cell size	NS	NS	NS	NS

[z]Two plants were measured per treatment. Figures are the means of 3 replications.
[NS,*,**]Nonsignificant (NS) or significant at the 5% (*) and 1% (**) levels.

creased. Total yields of all treatments did not differ significantly.

Michigan plants produced greater early yield than Florida plants in 1981 (Table 4). Early tomato yield increased with increasing root cell size; plants grown in 175 cells produced more than twice the early yield of plants grown in 080 cells. Total fruit yield also increased with root cell size. Plants grown in 175-size cells produced up to 25% more total yield than those grown in 080 cells.

Space between plants in flats had less effect on transplant size than did the volume of the root cells in which the transplants were produced. Tomato leaf area and shoot dry weight at 15 and 30 days after seeding increased with increased root cell size (Table 5). Plants grown at the wide spacing had increased shoot dry weight at both sampling dates, but not a corresponding increase in leaf area. There were no significant interactions between cell size and spacing.

Early yield of Michigan and Florida tomatoes was highly correlated with the volume of root cells in which the transplants were grown (Fig. 1). This correlation agrees with the findings of other researchers (6, 7, 9, 12). Plants with large root systems appear to suffer less transplant shock; thus, they come into production sooner than plants from smaller cells. This advantage probably is partially due to increased root development and reduced root binding in the large cells (6), which enhances early establishment of plants in the soil. The increased cost of grow-

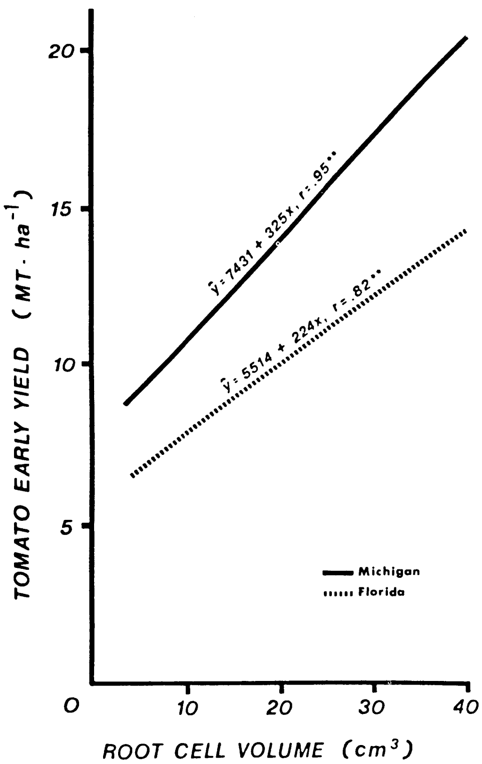

Fig. 1. The effect of root cell volume on early yield of 'Pik-Red' tomatoes, 1981.

ing plants in large cells may be overcome partially by increased early yields.

Michigan-grown tomato transplants were dark green at 4 weeks after seeding, whereas Florida-grown plants had reduced leaf area and were somewhat chlorotic. Cultural practices used in the production of the transplants probably had a major influence on their quality and appearance. Michigan-grown plants received considerably more N than did Florida plants, as well as additional P and K. Speedling's practice of fertilizing transplants with low concentrations of N (30 ppm) and withholding nutrients during the last week of production to harden the transplants most likely contributed to the relatively small transplant size and reduced early yields of Florida plants. Speedling has indicated recently that they have changed their fertilization and hardening practices in an attempt to improve quality of transplants.

The volume of the root cells and the fertilization practices during transplant production had a great effect on the condition of the transplants and on early fruit yield in the field. However, the small, slow-growing transplants usually produced total yields similar to the large, vigorous plants.

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