Proc. Fla. State Hort. Soc. 92:198-200. 1979.

EFFECT OF STORAGE TEMPERATURE AND DURATION ON QUALITY, SURVIVAL, AND YIELD OF CONTAINERIZED TOMATO TRANSPLANTS[1]

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Additional index words. marketable yield, wilt, decay, leaf color.

Abstract. **In 2 storage tests, containerized tomato transplants were stored at 40°F (4.4°C), 50°F (10°C), 55°F (12.8°C), 60°F (15.6°C), and 70°F (21.1°C) for 5, 10, and 15 days. The transplants were evaluated after storage for leaf color, wilt, decay, and height of plant. In a field test, transplants stored at 40°F, 55°F, and 70°F for 5, 10, and 15 days were planted and evaluated on the basis of survival, growth, and yield of tomatoes. In the storage tests, the transplants stored at 40°F had more green leaves and generally looked the best. The storage temperatures had no effect on wilt or decay. The height of transplants stored at 70°F increased during storage. In the field test, tomato plants that had been stored at 40°F for 10 and 15 days, 55°F for 15 days, and 70°F for 10 and 15 days had the lowest survival rate, initial growth, and yield of tomatoes. Storage of tomato transplants generally delayed initial plant growth, blossoming, and fruit harvest; and the delay was proportionate to the duration of storage.**

Fresh market tomatoes are grown from direct seeding or from transplants grown outdoors or in greenhouses. Many transplants are grown in Georgia for shipment to northern growing areas (3). However, some transplants are also grown in Florida for shipment to other areas within the state and to other states. Some Florida growers of fresh-market tomatoes use transplants to get an earlier harvesting start, or after winter freeze has damaged seedling plants.

Past studies (1, 4, 5) showed that the best temperatures for shipping and storing field-grown bare-rooted tomato transplants were between 50 and 60°F (10.0 - 15.6°C) (2). However, those studies were conducted on field-grown transplants. Tomato transplants are also grown in greenhouses or cold frames, generally near the tomato-producing areas. Transplants are also grown in greenhouses as containerized plants in specially designed styrofoam trays, usually called Speedling® trays. The conical cells are 1- (2.5 cm), 1.75- (4.4 cm), or 2-inches (5.1 cm) square at the opening and 3 inches (7.6 cm) deep. Such plants, with the soil mixture intact around the roots, are being shipped locally and to other producing areas of the country. Sometimes shipments are received when the fields are not ready for planting due to adverse weather. So, in addition to shipment, the plants must withstand temporary storage.

The objectives of this study were to determine the optimum storage-shipping temperature and duration of storage for tomato transplants grown in Speedling® trays.

Materials and Methods

Storage tests. Two storage tests were conducted with commercially grown containerized (1-inch openings) tomato transplants, cultivar 'Walter', at various temperatures: 40°F (4.4°C), 50°F (10°C), 55°F (12.8°C), 60°F (15.6°C) and 70°F (21.1°C). In both tests, one box of about 500 plants was stored at each storage temperature. After 5, 10, and 15 days of storage, 150 plants were removed at random from each box and evaluated for leaf color, wilt, and decay according to the numerical system shown in Table 1. Additionally, every 10th plant was measured from its base to the top of the growing point.

Field test. A field test was conducted with cultivar 'Walter' tomatoes to compare transplant survival, growth, and tomato yield. Commercial boxes of containerized (1-inch openings) transplants were stored at 40°F, 55°F, and 70°F for 5, 10, and 15 days. On the 15th day, the plants were removed from storage and, along with a control box (plants harvested that day), were taken to Homestead, Florida, for planting. The plants representing 10 treatments (3 temperatures by 3 storage periods and the control) were planted on January 17, 1979 on Rockdale soil in double row beds mulched with plastic. The plots were 6 x 14 feet (1.8 x 4.3 m), and the plants were spaced about 1 foot (0.3 m) apart. A 10-foot (3.0 m) section of the bed containing 20 plants was used for field survival, growth, and yield evaluations. A randomized complete block design with four replications was used. On February 15, field survival and plant growth (height and width) were recorded; and on March 28, additional observations on growth were made. Ripe and mature green tomatoes were harvested on April 11 and 23, and were sized and graded according to U.S. Standards and Grades.

All data were subjected to analysis of variance.

Results and Discussion

Storage tests. The lower the storage temperature, the better was the color rating of the plants (Table 2), except for plants stored at 70°F. Most of the leaves on the plants

[1]Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department to the exclusion of other products that may also be suitable.

Table 1. Rating descriptions for leaf color, wilt, and decay.

Condition	Numerical Rating				
	1	2	3	4	5
Leaf color[z]	All green	Mostly green	Green/brown	Mostly brown	All brown
Wilt	None	Trace	Slight	Moderate	Severe
Decay	None	Trace	Slight	Moderate	Severe

[z]Brown leaves generally fall off plant when handled.

Table 2. Condition rating for color, wilt, decay and height (inches) of tomato transplants stored for 5, 10 and 15 days at various temperatures.[z]

Storage period	Rating	Temperature					
		40°F	50°F	55°F	60°F	70°F	Average[y]
5 days	Color	1.52	2.25	3.07	3.16	2.75	2.55 a
	Wilt	1.00	1.02	1.00	1.00	1.02	1.01 a
	Decay	1.00	1.13	1.00	1.01	1.04	1.04 a
	Height	4.67	4.58	4.46	4.42	5.39	4.70 a
10 days	Color	1.66	3.25	3.31	3.53	3.29	3.01 b
	Wilt	1.04	1.02	1.04	1.02	1.43	1.11 b
	Decay	1.03	1.02	1.00	1.01	1.60	1.13 a
	Height	4.52	4.45	4.34	4.76	5.13	4.64 a
15 days	Color	2.30	3.32	4.07	4.02	3.06	3.35 c
	Wilt	1.08	1.17	1.34	1.17	1.50	1.25 c
	Decay	1.05	1.00	1.09	1.23	1.17	1.11 a
	Height	4.66	4.68	4.95	4.89	5.79	4.99 b
Average[y]	Color	1.82 a	2.94 b	3.48 c	3.57 c	3.03 b	
	Wilt	1.04 a	1.07 a	1.13 a	1.06 a	1.32 a	
	Decay	1.02 a	1.05 a	1.03 a	1.08 a	1.27 a	
	Height	4.61 a	4.57 a	4.58 a	4.69 a	5.44 b	

[z]Each value is based on 300 plants (150 plants per test) except for height, which is based on 30 plants (15 plants per test).
[y]Values for the same response within a column or row followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

stored at 55°F and 60°F turned brown and fell off. At lower temperatures, particularly 40°F, very few of the leaves turned brown. The leaves of the plants stored at 70°F turned yellow, but the top, new leaves were light green. There was no difference in the wilt or decay rating by storage temperature. Between each of the 3 storage periods, plants stored at 70°F grew about 0.8 inches (2.0 cm) more than those stored at the other temperatures. Color and wilt ratings, but not decay ratings, increased significantly between each period of storage. The average height of plants stored for 15 days was 0.3 inches (0.8 cm) taller than that of plants stored for either 5 or 10 days. This increase most likely was due to differences in growth among plants stored at 70°F rather than length of storage. Containerized tomato plants continue to grow during shipment and storage because of soil media and moisture remaining around the roots, particularly at higher temperatures.

Field test. Survival, growth, and condition of the control and stored plants are shown in Table 3. Survival was lowest for plants that had been stored for 15 days at 40°F. Our results for containerized plants agree with earlier results obtained by Lutz and Hardenburg (2) for bare-rooted transplants. Survival of plants stored 5 days at 70°F was significantly lower than that of plants stored 5 days at either 40°F or 55°F. However, survival of plants stored 10 and 15 days at 70°F was higher than that of plants stored 5 days at 70°F. This may seem odd, but during the first 5 days or more of storage at 70°F, the plants continued to grow; then the plants stopped growing, hardened, and were able to withstand the shock of transplanting. Several other researchers (1, 2, 3) reported similar results. Differences in plant size were evident about 1 month after transplanting, but not after about 2 months. Also, 2 months after transplanting, differences in number of fruit and number of blossoms were evident. Generally, the longer the storage time, the greater was the delay in blossoming and fruit set.

Yield of tomatoes was directly related to length of storage (Table 4). The total marketable yields of tomatoes were highest for plants not stored and for plants stored 5 days at 40°F, 55°F, and 70°F. Though these yields were not significantly different, they were significantly higher than those for all other combinations of storage temperature and lengths of storage. Of plants stored for 10 days, those that had been at 55°F gave the highest yield of total marketable tomatoes. There was no difference between the total marketable yields from plants stored 15 days at the three storage

Table 3. Survival, growth, and condition of plants by treatment in field tests at Homestead, Florida.[z]

Treatment		Plant survival[y] (percent)	Plant size height x width[y] (inches²)		Plant condition	
Temperature	Storage period		February 20	March 28	Fruit	Blossoms
Control	No storage	100.0 a	92 a	445 a	Many	Few
40°F	5 days	98.8 ab	85 b	445 a	Many	Few more
40°F	10 days	98.8 ab	52 de	462 a	Fewer	More
40°F	15 days	86.3 d	24 g	458 a	None	Many
55°F	5 days	100.0 a	75 c	462 a	Fewer	More
55°F	10 days	97.5 b	57 d	491 a	Few	Many
55°F	15 days	92.5 c	32 f	433 a	None	Many
70°F	5 days	93.8 c	58 d	440 a	Few	Many
70°F	10 days	97.5 b	55 d	475 a	Few	Many
70°F	15 days	97.5 b	48 e	495 a	Few	Many

[z]Plants were planted on January 17, 1979. Plant survival was recorded on February 20; plant size, on February 20 and March 28; and plant condition, on March 28.
[y]Values within a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Table 4. Yield of tomatoes by harvest and treatment in field test at Homestead, Florida.[z]

Treatment		Yield (tons/acre)[y]				
		Marketable				
Temperature	Storage period	No. 1	No. 2	No. 1+2	Color	Cull
		Harvest 1				
Control	No storage	5.3 a	2.4 a	7.7 a	3.0 a	1.0 a
40°F	5 days	5.1 a	2.4 a	7.5 a	2.5 a	1.2 a
40°F	10 days	3.0 c	1.5 bc	4.5 bc	0.9 c	1.2 a
40°F	15 days	2.0 d	0.9 c	2.9 d	0.0 e	0.7 ab
55°F	5 days	5.7 a	2.2 a	7.9 a	2.6 a	0.8 ab
55°F	10 days	3.2 c	2.0 ab	5.2 bc	0.7 cd	1.1 a
55°F	15 days	2.4 cd	1.2 c	3.6 cd	0.1 de	0.8 ab
70°F	5 days	4.3 b	2.3 a	6.5 ab	1.7 b	1.1 a
70°F	10 days	2.6 c	1.7 bc	4.3 cd	0.5 cde	1.2 a
70°F	15 days	2.5 c	1.5 bc	4.0 cd	0.4 cde	0.4 b
		Harvest 2				
Control	No storage	2.1 c	1.1 b	3.2 b	1.9 a	0.5 a
40°F	5 days	2.2 c	1.3 ab	3.5 b	1.9 a	0.8 a
40°F	10 days	2.3 bc	1.3 ab	3.6 b	1.4 ab	0.6 a
40°F	15 days	3.8 a	1.6 a	5.4 a	0.8 ab	0.5 a
55°F	5 days	2.0 c	1.5 a	3.5 b	1.9 a	1.0 a
55°F	10 days	2.8 b	1.5 a	4.3 ab	1.6 a	0.5 a
55°F	15 days	3.5 a	1.4 ab	4.9 a	0.5 b	0.7 a
70°F	5 days	3.0 b	1.4 ab	4.4 ab	1.3 ab	0.7 a
70°F	10 days	2.9 b	1.6 a	4.5 ab	1.1 ab	0.8 a
70°F	15 days	3.4 ab	1.4 ab	4.8 a	1.8 a	0.6 a
		Total				
Control	No storage	7.4 a	3.5 a	10.9 a	4.9 a	1.5 a
40°F	5 days	7.3 a	3.7 a	11.0 a	4.7 a	2.0 a
40°F	10 days	5.3 b	2.8 ab	8.1 c	2.3 c	1.8 a
40°F	15 days	5.8 b	2.5 b	8.3 c	0.8 e	1.2 a
55°F	5 days	7.7 a	3.7 a	11.4 a	4.5 a	1.8 a
55°F	10 days	6.0 b	3.5 a	9.5 b	2.3 c	1.6 a
55°F	15 days	5.9 b	2.6 b	8.5 c	0.6 e	1.5 a
70°F	5 days	7.3 a	3.7 a	11.0 a	3.0 b	1.8 a
70°F	10 days	5.5 b	3.3 a	8.8 c	1.6 d	2.0 a
70°F	15 days	5.9 b	2.9 ab	8.8 c	2.3 c	1.0 a

[z]Harvest 1 made on April 11 and harvest 2 on April 23. Values within a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.
[y]1 ton per acre = 2.2417 metric tonnes per hectare.

temperatures. Generally, the amount of cull tomatoes was the same regardless of treatment. The yield of U.S. No. 1 and U.S. No. 2 tomatoes was proportioned to total yield. Length of storage affected the yield of tomatoes by harvest. Five days' storage of tomato plants at 40° or 55°F did not affect the yield of marketable tomatoes as compared to the yield of unstored plants at harvest 1. Five days' storage at 70°F did affect the yield of marketable tomatoes but not significantly. Among the control plants and plants stored for 5 days, those that tended to yield more fruit at harvest 1 tended to yield less at harvest 2; therefore, the total yield of tomatoes were not significantly different. Plants stored for 10 and 15 days yielded more fruit at harvest 2 than control plants and plants stored for 5 days.

Our data indicate that temperatures between 50-55°F are the most desirable temperature for storage of containerized plants when all factors are considered. This finding corresponds with the finding of Lutz and Hardenburg (2) that bare-rooted plants store best at 50 to 60°F. However, for shipping-storage times of 5 days or less a temperature of 40°F is more desirable. Plants should not be stored longer than 10 days, regardless of temperature.

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