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COMPARISON OF TOMATO CULTIVARS IN GROWTH CHAMBERS AND IN AN UNHEATED STRUCTURE

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TREMBLAY-DEVEAU E. and ORMROD D. *Comparison of tomato cultivars in growth chambers and in an unheated structure.* BIOTRONICS **17**, 1–8, 1988. The growth and yield of six cultivars of greenhouse and field tomato in use in North America or the United Kingdom were assessed in growth chambers at four temperatures and compared with growth and yield in an unheated plastic-covered structure. The growth chambers were operated at day/night temperature regimes of 23/17, 23/8, 36/17, and 36/8°C. Differences among cultivars were greatest at 23/8°C day/night temperature. The U.K. cultivar Alfresco was the highest yielding cultivar at 23/8°C. In the unheated protected structure the cultivars Alfresco and Sigmabush, another U.K. cultivar, yielded the most high quality fruits. Leaf rolling, truss abortion, and deformed fruit occurred in most cultivars at the 36°C day temperature in the growth chambers. Leaf rolling, blotchy ripening, greenback and fruit cracking occurred in most cultivars in the unheated protected structure. The growth chamber and unheated protected structure identified similar differences among cultivars.

Key words: *Lycopersicon esculentum* Mill.; tomato; temperature; adaptation; controlled environment; protected cultivation; physiological disorders.

INTRODUCTION

One of the most important environmental factors for tomato plant growth and yield is a favorable temperature, as tomato growth is slow in cool temperatures and fruit set is sensitive to temperatures below 10°C (*11*). For this reason, the cool outdoor spring growing conditions typical of north temperate regions do not favour tomato production in the field. Planting must be delayed until favorable temperatures are experienced, resulting in late fruiting and missed marketing opportunities for fresh fruit. The use of protected unheated structures has been adopted in some regions (*3*) in an attempt to reduce energy costs compared with conventional greenhouses and to begin vegetable production earlier in the spring. Tomato plants are grown in a plastic structure with no supplemental heat, to supply the fresh market with vegetables at times when local field-grown crops are not available. Plants grown in such unheated structures are subject to temperature stress. They can be exposed to cool day and night temperatures in cloudy weather and to warm days and cool nights in sunny weather.

The selection of the best cultivar for such production conditions is an important pre-requisite to the use of unheated structures. Growth chambers have been used for screening plant material for response to environmental variables. For example, Kramer (*9*) reported growth chamber experiments on Monterey Pine which demonstrated that growth of this tree was very sensitive to high night temperatures, which explained its success in New Zealand. The objective of this research was to evaluate the performance of several tomato cultivars in growth chambers under four distinct and possibly stressful temperature regimes and in a protected unheated structure and to compare the two methods of estimating cultivar performance.

Four cultivars in use in North America ('Springset', 'Basketvee', 'Ultra Girl', and 'Dombito'), and two cultivars from the United Kingdom ('Sigmabush' and 'Alfresco') were studied. 'Springset', 'Basketvee' and the U.K. cultivars were determinate; the others were indeterminate.

MATERIALS AND METHODS

Growth chamber experiments

Four Conviron reach-in growth chambers (Model EY15) were used. Inside dimensions of each growth chamber were 1.55 m high, 0.80 m deep and 1.85 m wide. The photosynthetic photon flux (PPF) was 325 μmoles m^{-2} s^{-1} as measured with an L1-190S quantum sensor and LI-185 meter (Li-Cor). The light source was an adjustable bank of lamps consisting of 165 W cool white fluorescent lamps and 60 W incandescent frosted lamps (75% and 25% input wattage respectively). Lights were adjusted weekly to maintain the desired PPF at upper plant canopy height. The photoperiod was 16 h with an abrupt change. Pots containing determinate cultivars were supported to raise the plants to about the same canopy level as the indeterminate cultivars. Outdoor air was drawn in to maintain CO_2 at ambient levels. The relative humidity was $70\pm10\%$; the 4 day/night temperature regimes were 23/17, 23/8, 36/17, and 36/8°C.

Six seeds of each cultivar were sown in 150 mm diameter plastic pots containing "Pro-mix BX" medium and grown at a day/night temperature of 27/21°C for 3 weeks before application of differential temperature treatments. Twelve days after sowing, the seedlings were thinned to one per pot, selecting for uniform size, and randomized among growth chambers. For the differential temperature treatment period, the pots were randomly arranged within the growth chambers. Plants were irrigated daily with complete nutrient solution (*5*). After the third harvest, an automated drip irrigation system was used to provide the mature plants with an intermittent supply of nutrient solution at the rate of about 825 ml per plant per day. Plants were pruned to one main stem by removing all side shoots and topped when they reached the 4-cluster stage.

The experiment was set out as a split plot design. The main plots consisted of a 2×2 factorial arrangement of day/night temperatures; the subplot consisted of the 6 cultivars. One plant per cultivar was used for each day/night temperature regime. The data for plants harvested after 62 days of differential temperature treatments were recorded. The experiment was repeated twice for a total of three

independent replications with random assignment of temperature to growth chambers in each replication.

Leaf area was determined at harvest using an automatic integrating area meter (Li-Cor Area Meter, model 3100). Numbers of fruits (marketable and non-marketable) were recorded for each plant. Fruits exhibiting deformities or physiological disorders were classified as non-marketable. Weights of marketable and non-marketable fruits were determined.

Prior to statistical analysis leaf area was transformed to natural logarithms, to stabilize treatment variances. Duncan's multiple range test was used for mean separations among cultivars. The reproductive measurements did not meet the assumption of homogeneity of variances required for multiple range testing in spite of transformation to natural logarithms, square root, or arcsine (*10*), so standard errors of treatment means only are reported.

Unheated protected structure experiment

The unheated protected structure was 3.6 m high, 10 m wide and 24 m long and covered with polyethylene. The house was ventilated by opening and closing doors and windows early in the morning and at night, respectively. As the season became warmer, the doors and windows were left open. A granular complete fertilizer was incorporated into the loamy sand soil of the unheated structure. Lines for trickle irrigation were laid on top of the soil at intervals of 30 cm before application of black plastic mulch.

Seeds for this experiment were sown in cell packs containing sphagnum peat in a lighted germinating room at a temperature of approximately 25°C. Seedlings were transplanted 11 to 15 days from sowing into individual 13 cm diameter green plastic pots containing a sphagnum peat mix. At transplanting from the pots into ground beds (6 weeks after sowing) the soil was drenched with fungicide and a starter solution was applied. Plants were fertilized four times during the growing season with a nutrient solution containing 128 ppm nitrogen. The plants were arranged in a double-row pattern using a spacing of 60 cm between double rows, 45 cm within double rows and 30 cm between the plants within a row.

Cultivars were compared in three separate groups: North American determinates, North American indeterminates and United Kingdom determinates. Each group of cultivars was arranged as a randomized complete block design with four replicates. Each experimental unit (plot) consisted of 5 plants. Plants were pruned to one main stem by removing side shoots. Temperature was recorded at six positions in the unheated structure. Average daily maximum air temperature was 32.0°C while the average minimum air temperature was 15.0°C, 3 m from the side of the unheated structure. The maximum air temperature was 42.0°C and the minimum 5.0°C.

Fruits were harvested about twice a week from July 6 to August 17. Fruits were counted and weighed, and graded according to a grading system for greenhouse tomatoes: No. 1, No. 2, or cull. As the variances were generally heterogeneous, only standard errors of treatment mean values are presented with the fruit data.

RESULTS AND DISCUSSION

Growth chamber experiments

After 62 days of differential temperature treatment in growth chambers, plants grown at 23/17°C had, in general, more leaf area than those grown at other temperatures (Table 1). 'Ultra Girl' and 'Sigmabush' had the largest and smallest (respectively) leaf areas. The other cultivars ranged between these two extremes. 'Sigmabush' grew similarly at 23/17 and 23/8°C. There were no significant differences among cultivars at 36/8°C.

Table 1. Leaf area (cm^2 $plant^{-1}$) at four temperatures in growth chambers

Group Cultivar	Day/night temperatures (°C)			
	23/17	23/8	36/17	36/8
North American indeterminate				
Ultra Girl	8400a[z]	7260a	3260a	1840[y]
Dombito	7800ab	5370abc	2620a	1380
North American determinate				
Basketvee	6290abc	4520bcd	1770b	1100
Springset	5320bcd	4910bcd	1580b	1180
United Kingdom				
Alfresco	4970cd	3440de	1700b	1210
Sigmabush	2840e	2860e	1360b	1000
$S\bar{y}$[x]	.124	.117	.124	.163

[z] Mean separation within columns by Duncan's multiple range test at $P<0.05$.
[y] Column without mean separation indicates that there were no significant differences among means at $P<0.05$.
[x] Standard error of treatment means; to be used with $\ln(\bar{y})$ only.

Table 2. Marketable fruit weights (g $plant^{-1}$) after 62 days at four temperatures in growth chambers

Group Cultivar	Day/night temperatures (°C)			
	23/17	23/8	36/17	36/8
North American indeterminate				
Ultra Girl	323	284	0	1
	(77)[a]	(37)	(0)	(1)
Dombito	406	180	2	1
	(151)	(100)	(.153)	(1)
North American determinate				
Basketvee	395	283	12	1
	(52)	(10)	(11.97)	(1)
Springset	285	300	0	0
	(69)	(98)	(0)	(0)
United Kingdom				
Alfresco	690	601	0	18
	(132)	(54)	(0)	(8)
Sigmabush	473	455	0	7
	(102)	(30)	(0)	(7)

[a] Standard error of treatment mean, $\bar{y}$.

Table 3. Marketable fruit number per plant after 62 days at four temperatures in growth chambers

Group Cultivar	Day/night temperatures (°C)			
	23/17	23/8	36/17	36/8
North American indeterminate				
Ultra Girl	16.3	10.0	0	1.7
	(5.0)[a]	(4.0)	(0)	(1.7)
Dombito	12.0	9.3	0.3	4.3
	(2.8)	(2.6)	(0.3)	(4.3)
North American determinate				
Basketvee	9.3	9.0	1.7	2.3
	(2.3)	(0.6)	(1.7)	(1.5)
Springset	12.0	12.0	0	0
	(4.0)	(2.3)	(0)	(0)
United Kingdom				
Alfresco	21.0	22.3	0	2.7
	(2.0)	(5.5)	(0)	(1.2)
Sigmabush	24.0	31.0	0	1.7
	(4.6)	(1.5)	(0)	(1.2)

[a] Standard error of treatment mean, $\bar{y}$.

Very little marketable fruit was obtained in the high day temperature regimes (36/17 and 36/8°C) (Table 2). Significant differences among cultivars in terms of marketable fruit weight occurred only at 23/8°C. 'Alfresco' had a significantly higher weight of marketable fruits than all the other cultivars except 'Springset' and 'Sigmabush'.

The United Kingdom cultivars performed, in general, best in terms of marketable fruit number at the moderate day temperature regimes (23/17 and 23/8°C) (Table 3). At 23/8°C, 'Sigmabush' had more marketable fruits than all the other cultivars except 'Alfresco'; the trend was similar at 23/17°C. There were no significant differences among cultivars at 36/17 or 36/8°C.

Cultivars grown at 36/8°C were stunted with short internodes, thick curled leaves, and enlarged sepals. Plants at 36/17°C exhibited the same characteristics as those at 36/8°C but to a lesser extent. All cultivars, both determinate and indeterminate, grown at 36/17 and 36/8°C exhibited leaf rolling. Truss abortion and deformed fruit were also noted at these two temperature regimes. Plants grown at 23/8°C had leaves with purple pigmentation.

Unheated protected structure experiment

The average yield of No. 1 fruit in the unheated structure varied widely among the cultivars (Table 4). This was also true for No. 2 and cull fruit, although the range was not as large. The United Kingdom cultivars ('Alfresco' and 'Sigmabush') were the highest yielding group with respect to No. 1 fruit. These cultivars tended to have lower yields of No. 2 and cull fruit than the other two groups. Both North American groups included a cultivar which had no or few good quality fruits in the unheated structure ('Ultra Girl' and 'Basketvee'); these two cultivars had high yields

Table 4. Fruit yield (g plant^{-1}) and diameter (cm) in the unheated protected structure

Group Cultivar	Grade			Fruit diameter
	No. 1	No. 2	Cull	
North American indeterminate				
Ultra Girl	152	1262	917	6.71
	(47)[a]	(100)	(218)	(.28)
Dombito	593	839	543	6.25
	(65)	(92)	(123)	(.28)
North American determinate				
Basketvee	0	623	1212	5.69
	(0)	(92)	(18)	(.83)
Springset	425	1201	298	6.73
	(107)	(137)	(51)	(.83)
United Kingdom				
Alfresco	1039	650	212	3.69
	(140)	(29)	(33)	(.41)
Sigmabush	756	436	112	3.36
	(119)	(42)	(29)	(.41)

[a] Standard error of treatment mean, $\bar{y}$.

of No. 2 and cull fruit. 'Dombito' and 'Springset' were medium yielding in the unheated plastic structure.

All cultivars except 'Ultra Girl' and 'Dombito' exhibited leaf rolling to a great extent. No fruit deformities were noted except for pear-shaped fruits. Ripening disorders, such as blotchy ripening, greenback, and cracking were common.

Comparison of performance in growth chambers and protected structures

The growth chamber and unheated protected structure identified similar differences among cultivars: 'Alfresco' was the highest yielding cultivar in both the protected structure and the growth chambers.

The U.K. cultivars were the first to bloom in the unheated structure (data not shown). However, yield of marketable fruit did not seem to be associated with the opening of the first flower since 'Basketvee' and 'Springset' flowered at almost the same time as 'Alfresco' but produced lower yields. The North American indeterminate cultivars had the greatest leaf areas; however, this was not positively correlated with fruit yield at any temperature.

The United Kingdom cultivars are determinate types which mature early. The ability of 'Alfresco' and 'Sigmabush' to produce fruit at the cool night temperature (8°C) in growth chambers and in the unheated structure may be related to better fruit set in these cultivars. The process of fruit set in 'Alfresco' and 'Sigmabush' may be more tolerant of lower night air temperatures than that in the other cultivars, leading to a greater yield under conditions of cool nights. The United Kingdom cultivars are more likely to have flowers with the anthers forming a regular cone which fully encloses the style and the stigma, as these cultivars are small-fruited. This type of flower structure leads to the best fruit-set under adverse conditions by providing maximum opportunity for self-pollination (*4*).

Plants grown at an extreme day temperature of 36°C in growth chambers exhibited leaf roll. The leaf roll did not seem to have a negative effect on yield since the United Kingdom cultivars exhibited a great deal of leaf rolling but had the highest yields. These cultivars may have the gene for curled leaves (wt), allowing greater exposure of the fruits and contributing to their earliness and more even ripening (*7*).

There were several fruit disorders observed in the unheated structure, which largely accounted for the No. 2 and cull fruit. Blotchy ripening was a common disorder, possibly due to water stress and imbalance of nitrogen and potassium in addition to low light intensity (*2*). Greenback was also quite common. Susceptibility to greenback is under genetic control (*6*); high fruit temperature (above 29°C) restricts the development of red colour, and temperatures above 38°C favour the maintenance of chlorophyll. A sharply demarcated region, usually green or yellow-green, then appears on the red fruit.

Cracking or splitting of tomato fruits was a characteristic of some cultivars; it appears to be under genetic control. However, calcium and moisture availability could be involved as well (*6*). Truss abortion occurred at high day temperatures (36°C) in growth chambers. According to Calvert (*1*), as temperature increases, carbohydrates become less available to the truss and more to the developing leaves. Deformed tomatoes were also obtained at high day temperatures (36°C). High temperature may prevent the formation or inhibit the transport of growth substances needed for cell division, so that the ovary wall does not close completely at the base of the style (*8*). This results in fruit deformities usually referred to as open locule fruits. The deformities associated with high day temperature (36°C) tended to mask the effect of cool night temperature (8°C). In consequence, a moderate day temperature (23°C) combined with a cool night temperature (8°C) in the growth chamber studies was preferable for screening of cultivars for low night temperature tolerance.

The United Kingdom cultivars provided by far the highest yield of No. 1 quality fruit in the present study but their smaller fruit size may limit consumer acceptance. Many of the larger fruited cultivars also yielded well but most of the fruit were of No. 2 or poorer quality. Similarity in the results between the 23/8°C growth chamber and the unheated protected structure trials demonstrates that a growth chamber could be useful for pre-screening tomato cultivars for tolerance to the temperature stresses that may occur in commercial protected structure production.

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