6. Hiraki, Y and Y. Ota. 1975. The relationship between growth inhibition and ethylene produced by mechanical stimulation in *Lilium longiflorum*. Plant & Cell Physiol. 16:185–189.
7. Jacobs, M.R. 1954. The effect of wind sway on the form and development of *Pinus radiata* D. Don. Austral. J. Bot. 2:35–61.
8. Jaffe, M.J. 1973. Thigmomorphogenesis: the response of plant growth and development to mechanical stimulation, with special reference to *Bryonia dioica*. Planta (Berl.) 114:143–157.
9. Jaffe, M.J. 1976. Thigmomorphogenesis: a detailed characterization of the response of beans (*Phaseolus vulgaris* L.) to mechanical stimulation. Z. Pflanzenphysiol. 77:437–453.
10. Larson, P.R. 1965. Stem form of young *Larix* as influenced by wind and pruning. Forest Sci. 11:412–424.
11. Leiser, A.T., R.W. Harris, P.L. Neel, D. Long, N.W. Stice, and R.G. Maire. 1972. Staking and pruning influence trunk development of young trees. J. Amer. Soc. Hort. Sci. 97:498–503.
12. Martin, E.V. and F.E. Clements. 1935. Studies of the effects of artificial wind on growth and transpiration in *Helianthus annuus*. Plant Physiol. 10:613–636.
13. Mitchell, C.A., H.C. Dostal, and T.M. Seipel. 1977. Dry weight reduction in mechanically-dwarfed tomato plants. J. Amer. Soc. Hort. Sci. 102:605–608.
14. Mitchell, C.A., C.J. Severson, J.A. Wott, and P.A. Hammer. 1975. Seismomorphogenic regulation of plant growth. J. Amer. Soc. Hort. Sci. 100:161–165.
15. Mohsenin, N.M. 1970. Physical properties of plant and animal materials. Vol. 1: Structure, physical characteristics, and mechanical properties. Gordon & Breach, New York.
16. Neel, P.L. 1970. Experimental manipulation of trunk growth in young trees. Proc. Intern. Shade Tree Conf. 46:25–30.
17. Neel, P.L. and R.W. Harris. 1971. Motion-induced inhibition of elongation and induction of dormancy in *Liquidambar*. Science 173:58–59.
18. Rao, V.P. 1938. Effect of artificial wind on growth and transpiration in the Italian millet, *Setaria italica*. Bul. Torr. Bot. C. 65:229–232.
19. Steucek, G.L. and L.K. Gordon. 1975. Response of wheat (*Triticum aesturiem*) seedlings to mechanical stress. Bot. Gaz. 136:17–19.
20. Telewski, F.W. and M.J. Jaffe. 1981. Thigmomorphogenesis: changes in the morphology and chemical composition induced by mechanical perturbation in 6-month-old *Pinus taeda* seedlings. Can. J. Forest Res. 11:380–387.
21. Vidosic, J.P. 1978. Mechanics of materials, p 5-1 to 5-37. In: T. Baumeister, E.A. Avallone, and T. Baumeister (eds.). Mark's handbook for mechanical engineers. McGraw-Hill, New York.

J. Amer. Soc. Hort. Sci. 108(5):805–809. 1983.

Root and Air Temperature Effects on the Flowering and Yield of Tomato

Athanasios P. Papadopoulos[1] and Herman Tiessen[2]
Department of Horticultural Science, University of Guelph, Guelph, Ont., Canada N1G 2W1

Additional index words. soil heating, hydroponics, energy conservation, *Lycopersicon esculentum*

Abstract. **Cultivars of greenhouse tomato (*Lycopersicon esculentum* Mill.) were grown in the greenhouse and in growth chambers to study the effects of root and air temperature on flowering and yield. A low air temperature of 19° (day)/14°C (night), during the fall crop, caused no reduction in yield when compared with the commonly used 22°/17° air temperature. A 13°/8° air temperature during the spring crop drastically reduced yield compared with the 19°/14°C air temperature. Flowering of 'Ohio MR-13' in growth chambers was delayed significantly at air temperatures of 24°/8° compared to 24°/17°, but the flowering of 'Vendor' was unaffected by air temperature treatments. Marketable yield of 'Vendor' was significantly higher at 24°/8° compared to the 24°/17° treatment, while the marketable yield of 'Ohio MR-13' was unaffected. At a constant, day air temperature of 24°, the amount of small fruit decreased as night air temperature was lowered from 17° to 8° and maturity was delayed as night air temperature was lowered from 14° to 8°. The effect of low air temperature on flowering and yield of tomatoes was large and could not be offset by increasing root temperatures. At air temperatures of 24°/17°, 24°/14°, and 24°/8°, marketable yields were affected adversely by the absence of root thermoperiodicity (day to night root temperature variation).**

Conserving energy while maintaining high yields has become a major objective of greenhouse vegetable growers. A possible way of achieving this goal is by operating greenhouses at lower air temperatures and this has prompted new interest in determining the optimum growing temperatures of greenhouse tomatoes.

Despite the great deal of time already spent in searching for the air and root temperature optima for greenhouse tomato cropping, confusion and uncertainty on this subject are still very common. One of the reasons for this uncertainty and confusion has been a series of recent publications suggesting that the night air temperature on tomato production can be reduced below normal greenhouse levels without any detriment to yield, provided that the roots are kept warm (9, 10, 15), contrary to the findings of other studies (7, 13, 16). Another source of confusion has been the disputed role of thermoperiodicity in the development of the tomato; some considered it of paramount importance (8, 16), others denied its importance (1, 11). Most of the variability in the published findings to date can be explained by the reported interaction of temperature with other environmental factors (15, 16, 17), with plant age (8, 15, 17), and with the genetic makeup of the experimental material (11, 17).

This investigation was undertaken to determine the effect of lowering air temperature or raising the root temperature on yield of greenhouse tomatoes.

Received for publication November 26, 1982. The authors gratefully acknowledge the statistical advice of I. McMillan, University of Guelph and V.A. Dirks, Agriculture Canada. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Present address: Research Station, Agriculture Canada, Harrow, Ont., Canada N0R 1G0.
[2]Professor.

Materials and Methods

Experiments were conducted in growth chambers using a soil mix culture system and in the greenhouse using a water culture system.

Growth chamber experiments. Three, 3-m^3 Controlled Environments, Model E15 reach-in chambers, fitted with movable "light banks" and having 73% input wattage of 1500-ma Cool-White fluorescent and 27% input wattage of extended-service incandescent lighting were used. The photon flux density in the growing area (15–20 cm lower than the plant apices) was maintained at 230–260 $\mu E\ s^{-1}m^{-2}$ (400–700 nm) throughout the experiment by frequent height adjustments of the "light banks". Radiation was measured with an LI-190S quantum sensor attached to a LI-COR Model LI-185 meter. The light (day) and dark (night) periods were equal (12 hr each) with an abrupt change. Relative humidity was measured with an aspirated psychrometer and maintained at 70 ± 5% during the day. The air flow was upwards between pots and makeup air ranged between 0.2 and 0.5 $m^3\ min^{-1}$, depending on plant growth stage.

Seeds of 'Ohio MR-13' and 'Vendor' were sown in "Jiffy 7" pots and kept at 27° ± 1°C in an E15 chamber until the first true leaves appeared. At this stage, seedlings were given a cold treatment (12 ± 1° day and night) for 3 weeks. The 4- to 5-week-old plants then were transplanted singly to 26-cm-diameter pots filled with a medium of soil, sphagnum peatmoss, and perlite (1 : 1 : 1 by volume) with pH adjusted to 6.5 with dolomitic limestone. Plastic tubing was set around the pots froming a coil through which warm water could be circulated for soil temperature control. To limit heat losses, the pots (with or without the plastic tubing coils around them) were set in 36-cm-diameter pots filled with perlite. These plants were transferred to the growth chambers, 8 plants in each, for treatment. This experiment was set out as a split-split plot design.

Factor A levels consisted of 3 night air temperature treatments 17° ±, 14° ±, and 8° ± 1°C and a uniform 24° ± 1° day air temperature in each chamber. Factor B levels consisted of 2 soil temperature treatments, "unheated" or "heated" to 24° ± 1°; each of them applied to 4 plants in each growth chamber. Factor C levels were represented by 2 cultivars, 'Ohio MR-13' and 'Vendor'. Each cultivar was replicated twice for each "night air" by "soil' temperature combination.

This experiment was conducted twice, interchanging chambers to reduce growth chamber error.

The opening date of each flower was determined; the number of flowers opened within 80 days from seeding was considered a measure of earliness of flowering. Fruit were harvested twice a week, graded for size and defects, and weighed. Fruit harvested within 140 days from seedling were considered early yield. Data from both experiments were combined and analyzed as a split-plot in time and space; treatment mean differences were evaluated by Tukey's (HSD) test at the 5% significance level.

Greenhouse experiments. A 1977 fall crop and a 1978 spring crop were grown in two, 150-m^2 greenhouses. All plants were started in "Jiffy 7" pots in the greenhouse and then placed 30 cm apart in a shallow stream of continually circulating nutrient solution (trough) in accordance with Cooper's description of Nutrient Film technique (NFT) cropping system (4). The troughs were arranged in twin rows 45 cm apart with the trough pairs on 135-cm centres. A modified Cooper nutrient solution (14) was used, controlled by measuring pH and electrical conductivity and maintaining them at 6.7 and 2.3 mmhos cm^{-1}, respectively. The nutrient solution was renewed at lengths of time inversely proportional to the size and metabolic activity of the plants. Except for the use of nutrient solution as a growing medium, the plants were grown in a conventional way reflecting as much as possible the common practices of the Ontario greenhouse tomato growers. Each experiment was set out as a split-split-plot design.

Fall 1977 crop. This crop was grown from June 3 to December 24. Factor A levels comprised 2 air temperatures: 22° ± 3°C (day)/17° ± 2° (night) and 19° ± 3/14° ± 2°. Factor B comprised 2 root temperatures (21° ± 1° and 27° ± 1°) realized by recirculating properly heated nutrient solutions through the root systems of the plants. The temperature control of each nutrient solution was achieved by immersion heaters. Both air and root (solution) temperatures were monitored and recorded. Factor C compared 4 cultivars ('Ohio MR-13', 'Tropic,' 'Jumbo', and 'Vendor'); each replicated 4 times for each air by root temperature combination.

Spring 1978 crop. This crop was grown from November 29 to July 6. Factor A comprised 2 air temperatures: 19° ± 3°C/14° ± 2° and 13° ± 3/8° ± 2°. The levels of Factors B and C were the same as in the 1977 Fall crop. All treatments were allocated and implemented in the same way as for the 1977 Fall crop.

Fruit were harvested twice a week, graded for size and defects, and weighed. Fruit harvested in the 1978 Spring crop before May 25, 1978, were considered early production. Data from each crop were analyzed as split-plots in space and treatment mean differences were evaluated by Tukey's (HSD) test at the 5% significance level. Each replicate in greenhouse 1 was made up of 10 plants while each replicate in greenhouse 2 was made up of 5 plants.

Results

Growth chamber experiments. Total yields and production of blossom-end rotted (BER) and cat-faced (CF) fruit, as well as the total number of flowers, were unaffected by the 3 air temperature treatments, 24°/17°C, 24°/14°, and 24°/8° (Table 1). There was a significant increase in small fruit produced when the night air temperature increased from 8° to 14° and from 14° to 17°. Total and marketable yields were not delayed when the night air temperature was dropped from 17° to 14°, but there was a significant delay in fruit production when the night air temperature dropped from 14° to 8° (Table 1). The regression of the number of early opened flowers on night air temperature was significant (F = 19.08; 22 d.f.) for 'Ohio MR-13', but not for 'Vendor' (Fig. 1). Conversely, the regression of marketable yield on night air temperature was significant (F = 8.14; 22d.f.) for 'Vendor', but not for 'Ohio MR-13' (Fig. 2). Total yield, BER, CF, and small fruit development were unaffected by the root temperature treatments (unheated and heated to 24°). Early total and marketable yields also were unaffected. Accordingly, the flowering or the earliness of flowering was unaffected by root temperature treatments. The only significant effect that root temperature had on yields was a higher marketable yield at the "unheated" treatment (Table 1). No significant interaction was observed between root and air temperature for any of the measured characters (data not shown).

Greenhouse experiments. In the Fall crop there were no significant differences in total or marketable yields or BER fruit due to different air temperature treatments applied. However, plants grown at 22°/17°C produced significantly more small fruit than those grown at 19°/14° (Table 2). More striking effects of the air temperature treatments on yield were found during the 1978 Spring crop (Table 3, 4). Due to variance heterogeneity

Table 1. Effects of air temperature, root temperature, and cultivar on tomato flowering and yield components; Fall 1977, and Spring 1978 growth chamber experiments.

Main effects	Total	Marketable	Blossom-end rot fruit	Cat-faced fruit	Small fruit	Early total[x]	Early marketable[x]	Early flowers[x]	Total (all) flowers
	Yield (g/plant or no. flowers/plant)								
Air temp means[z,y]									
24°/17°C	2118	1199	47	250	597 a	1377 a	946 a	12 a	34
24°/14°	2095	1239	59	380	465 b	1286 a	852 a	11 b	35
24°/8°	1684	1213	58	159	215 c	436 b	358 b	8 b	32
Root temp means[y]									
Unheated	2049	1329 a	50	277	405	1082	782	10	33
Heated to 24°	1883	1104 b	60	249	445	984	655	10	34
Cultivar means[y]									
Ohio MR-13	1637 b	866 b	85 a	180	519 a	867 b	551 b	10	35 a
Vendor	2295 a	1569 a	24 b	347	332 b	1198 a	886 a	11	32 b
Significance of F									
Air temp	NS	NS	NS	NS	*	*	*	*	NS
Root temp	NS	*	NS	NS	NS	NS	NS	NS	NS
Cultivar	*	*	*	NS	*	*	*	NS	*

[z]Day/night air temp.
[y]Mean separation within columns by Tukey's test, 5 % level.
[x]Early yield is the yield harvested within 140 days from seeding; early flowers is the number of flowers opened within 80 days from seeding.
NS,*Nonsignificant (NS) or significant at 5% level.

between yield data at 19°/14° and 13°/8° air temperature, differences among yield means at the 2 air temperatures were tested by means of a Cochran's approximation of the t-test for samples with unequal variances (t') (3). The application of this test to the air temperature yield means of the 1978 Spring crop showed that both marketable and unmarketable fruit production were reduced and delayed severely at the 13°/8° temperature ($P <$ 5%; Table 3, 4). Although no study of the interaction between air temperature and cultivar was possible in the 1978 Spring greenhouse experiment, total yield of 'Vendor' was less adversely affected than that of the other 3 cultivars by the drop of the air temperature from 19°/14° to 13°/8° (Table 4). There were no significant yield differences due to root temperature in either the 1977 Fall or 1978 Spring crops (Table 3, 4). Similarly, there were no significant yield differences during the 1977 Fall crop due to air by root temperature interaction (data not shown). In the 1978 Spring crop, a variance heterogeneity did not allow any test of the air by root temperature interaction.

'Vendor' always produced higher total yields than 'Ohio MR-13' (Table 1, 2, 4). 'Vendor' also produced higher early mar-

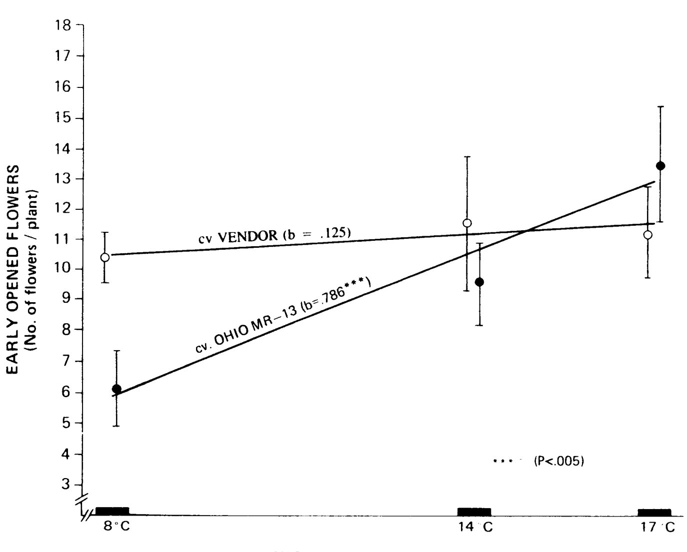

Fig. 1. Response of early flowering to night air temperature in 'Vendor' and 'Ohio MR-13' tomato. Means (○ 'Vendor'; ● 'Ohio MR-13') are averages of 8 observations; vertical bars represent SD of samples. The regression lines differ significantly ($P <$ 5%).

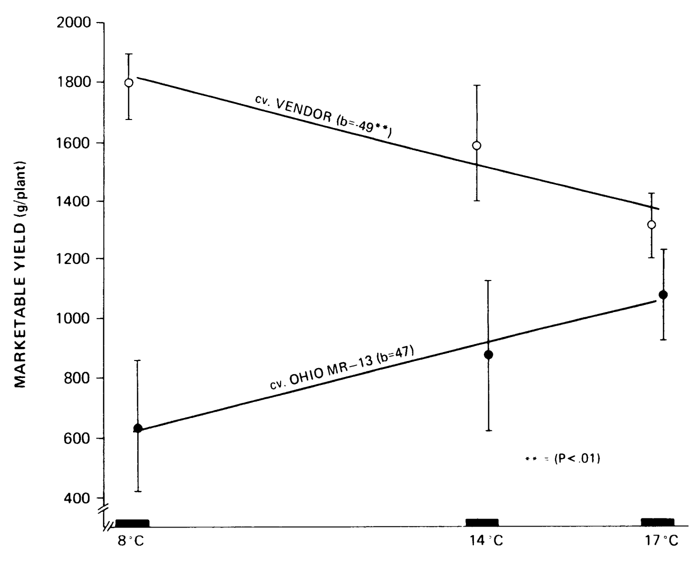

Fig. 2. Response of marketable yield to night air temperature in 'Vendor' and 'Ohio MR-13' tomato. Means (○ 'Vendor'; ● 'Ohio MR-13') are averages of 8 observations; vertical bars represent SD of samples. The regression lines differ significantly (P < 0.5%).

Table 2. Effects of air temperature, root temperature, and cultivar on tomato yield components; Fall 1977 greenhouse crop.

	Yield (g/plant)				
Main effects	Total	Marketable	Blossom end-rot fruit	Cat-faced fruit	Small fruit
Air temp means[z,y]					
22/17°C	3152	2023	139	596	375 a
19/14°	2740	1752	118	561	307 b
Cultivar means[y]					
Ohio MR-13	2404 c	1425 b	451 a	152 d	373 b
Tropic	3341 a	2223 a	8 b	1015 a	91 c
Jumbo	3126 bc	2166 a	17 b	712 b	217 bc
Vendor	2893 b	1734 b	39 b	434 c	683 a
Significance of F					
Air temp	NS	NS	NS	NS	*
Root temp	NS	NS	NS	NS	NS
Cultivar	*	*	*	*	*

[z]Day/night air temp.
[y]Mean separation within columns by Tukey's test, 5% level.
[NS,*]Nonsignificant (NS) or significant at 5% level.

ketable, early total, and overalll marketable yields than 'Ohio MR-13' in the growth chambers, but its relative performance under greenhouse conditions was not consistent. Furthermore,

Table 3. Effects of air temperature, root temperature, and cultivar on early tomato yield components[z]; Spring 1978 greenhouse crop.

Treatment			Yield (g/plant)			
Air temp[y] (°C)	Root temp (°C)	Cultivar	Total	Marketable	Cat-faced fruit	Small fruit
19/14	21	Ohio-MR-13	1596	891	570	115
		Tropic	1355	331	945	79
		Jumbo	1571	533	918	119
		Vendor	1758	587	1013	156
	27	Ohio-MR-13	1488	691	681	116
		Tropic	1640	328	1241	70
		Jumbo	1652	591	968	93
		Vendor	1772	541	1110	121
Cultivar means[w]						
19/14°C		Ohio-MR-13	1532	791 a	625 b	115 ab
		Tropic	1497	329 b	1093 a	74 b
		Jumbo	1611	562 ab	943 ab	106 ab
		Vendor	1765	564 ab	1061 a	138 a
Significance of F[x]						
Root temp (RT)			NS	NS	NS	NS
Cultivar (C)			NS	*	*	*
RT × C			NS	NS	NS	NS

[z]Early yield is the yield harvested until March 25, 1978.
[y]Day/night air temp; plants growing at 13°/8°C had no yield by March 25, 1978.
[x]Significance of F refers only to the 19°/14°C air temp treatment.
[w]Mean separation within columns by Tukey's test, 5% level.
[NS,*]Nonsignificant (NS) or significant at 5% level (*).

Table 4. Effects of air temperature, root temperature, and cultivar on tomato yields; Spring 1978 greenhouse crops.

Treatment			Yield (g/plant)			
Air temp[z] (°C)	Root temp (°C)	Cultivar	Total	Marketable	Cat-faced fruit	Small fruit
19/14	21	Ohio-MR-13	2433	1455	674	288
		Tropic	2906	1052	1673	181
		Jumbo	3220	1564	1420	237
		Vendor	2898	1139	1407	351
	27	Ohio-MR-13	2311	1270	780	260
		Tropic	3260	962	2119	179
		Jumbo	3215	1598	1404	212
		Vendor	3046	1112	1546	388
13/8	21	Ohio-MR-13	216	4	212[x]	---[x]
		Tropic	342	5	337	---
		Jumbo	417	0	417	---
		Vendor	513	3	510	---
	27	Ohio-MR-13	215	0	215[x]	---[x]
		Tropic	366	0	366	---
		Jumbo	352	0	352	---
		Vendor	545	19	526	---
Cultivar means[y]						
19/14°C		Ohio-MR-13	2372 b	1326 ab	727 c	274 b
		Tropic	3083 a	1007 b	1896 a	180 c
		Jumbo	3218 a	1581 a	1412 b	224 bc
		Vendor	2972 a	1125 b	1476 b	369 a
Cultivar means[y]						
13/8°C		Ohio-MR-13	215 c	2 a	213 c[x]	---[x]
		Tropic	354 b	2 a	352 b	---
		Jumbo	384 b	0 a	384 b	---
		Vendor	529 a	11 a	518 a	---
Significance of F						
Root temp (RT)			NS	NS	NS	NS
Cultivar (C)			*	*	*	*
RT × C			NS	NS	NS	NS

[z]Day/night air temp.
[y]Mean separation within columns by Tukey's test, 5% level.
[x]All cat-faced fruit at the air temperature of 13/8°C also were small.
[NS,*]Nonsignificant (NS) or significant at 5% level (*).

'Vendor' produced less small fruit than 'Ohio MR-13' in growth chambers, but more than 'Ohio MR-13' in the greenhouse (Table 1, 2, 3, 4). In the greenhouse, 'Tropic' produced the highest total and 'Tropic' and 'Jumbo' the highest marketable yields in the 1977 Fall crop (Table 2); 'Tropic', 'Jumbo' and 'Vendor' produced the highset total and 'Jumbo' the highest marketable yield in the 1978 Spring crop (Table 4). 'Tropic' was the most susceptible cultivar to cat-facing followed by 'Jumbo' and 'Vendor', while 'Ohio MR-13' was the least susceptible (Table 2). In the growth chamber experiment, however, the differences in CF between 'Ohio MR-13' and 'Vendor' were not significant.

'Ohio MR-13' proved to be the most susceptible to BER, while no significant differences were observed among the 3 other cultivars (Table 1 and 2).

Discussion

A minimum air temperature setting of 19°/14°C during a Fall greenhouse tomato crop caused no reduction in yield, compared with a normal 22°/17°. These results suggest that energy can be conserved when growing a Fall greenhouse tomato crop by maintaining an air temperature of 19°/14°, rather than 22°/17°, without any yield loss.

Lower and later yields occurred in the 1978 Spring greenhouse crop at the 13°/8°C air temperature compared to 19°/14°. This severe yield decline, combined with the relative uniformity of yields at the 3 air temperature treatments in the growth chamber experiments (24°/17°, 24°/14°, 24°/8°), suggests that tomato fruiting depends heavily on the day air temperature when the night air temperature is low (8°). Similar responses were reported by Went (16), who obtained a normal fruit development at 26°/5° air temperature but a total absence of development at 5°/5°. The limited fruit production at low air temperature (13°/8°) in the greenhouse is believed to have been caused by poor pollen viability, slow pollen tube growth, and too high a stigma level in the anther cone (2), all of which have been shown to cause a reduction in seed set, fruit size, and earliness (5). Data from the growth chamber experiments have shown that when the night air temperature dropped from 17° to 8°, there was a significant delay in the flowering of 'Ohio MR-13', but not of 'Vendor'. Also, when the same night air temperature range was considered, the higher ability of 'Vendor' to retain early flowers was reflected in higher marketable yields, as compared wiht 'Ohio MR-13'. These effects of the night air temperature on earliness of flowering and marketable yields, although cultivar-dependent, indicate that when the day air temperature is optimum, the night air temperature becomes the factor controlling marketable yield and earliness. These results are in agreement with the findings of others (12, 16), indicating that certain tomato cultivars have a wider tolerance to lower night air temperatures than others. The practical implication is that considerable energy can be conserved by the greenhouse industry through selective use of cultivars such as 'Vendor' which allow the use of a night air temperature as low as 8°, coupled with a day air temperature of 24°, without any reduction in marketable yield; a delay in production is to be expected, however, under these conditions.

It was noted in both growth chamber and greenhouse studies that whenever the day air temperature was not low enough to inhibit seedset, any increase in either the day and night air temperature in the greenhouse or in the night air temperature in the growth chambers was followed by a significant increase in the amount of small fruit. The tendency towards smaller fruit at higher air temperatures was previously reported by Verkerk (15).

It has been proposed that, provided a favorable air temperature is maintained, there is no need to heat roots (7). Such a proposition implies that any beneficial effect from root heating would best express itself as a correction of the adverse effect of low air temperature. Had this been true, positive results from root warming would have been observed in the 1978 Spring greenhouse experiment where the low air temperature drastically reduced yields. Actually, the results obtained from both the greenhouse and growth chambers did not match such expectations. Greenhouse results, in particular, indicated that the adverse effect of low air temperatures on yield is large and cannot be offset by higher root temperatures. These results agree with those of some previous studies (7, 13, 17) but not with those of others (6, 9, 10, 12). Actually, the growth chamber experiments indicated that, instead of beneficial effects, root warming reduced marketable yields. This response indicates either a reduction in the yields because of supraoptimal root temperatures in heated plants (24°/24°C, day/night) or a beneficial yield effect of fluctuating root temperatures (24°/17°, 24°/14°, 24°/8°, day/night) in unheated plants. The former hypothesis seems unlikely since a root temperature of 24° repeatedly has been considered as being within the optimal range (6, 10, 17). The results of this study have shown that no beneficial yield effect is realized with root heating and possibly an adverse situation is created when root heating upsets root thermoperiodicity. Beneficial effects of fluctuating air temperatures on tomato yield originally were reported by Went (16) and later acknowledged by Hussey (8). This, however, is the first report suggesting a significant yield response of tomato to root thermoperiodicity. Further investigations are needed on the day air temperature threshold for greenhouse tomatoes at a night air temperature of 8°.

Literature Cited

1. Calvert, A. 1964. The effects of air temperature on growth of young tomato plants in natural light conditions. J. Hort. Sci. 39:194–211.
2. Charles, W.B. and R.E. Harris. 1972. Tomato fruit set at high and low temperatures. Can. J. Plant Sci. 52:497–506.
3. Cochran, W.G. and G.M. Cox. 1957. Experimental designs, 2nd ed. Wiley, New York.
4. Cooper, A.J. 1976. Nutrient-film technique of growing crops. Grower Books, London.
5. Dempsey, W.H. and J.E. Boynton. 1965. Effect of seed number on tomato fruit size and maturity. Proc. Amer. Soc. Hort. Sci. 86:575–581.
6. Gerick, W.F. and J.R. Tavernetti. 1936. Heating of liquid culture media for tomato production. Agr. Eng. 17:141–142, 184.
7. Hoagland, D.R. and D.I. Arnon. 1938. The water-culture method for growing plants without soil. Calif. Agr. Expt. Sta. Cir. 347.
8. Hussey, G. 1965. Growth and development in the young tomato. III. The effect of night and day temperatures on vegetative growth. J. Expt. Bot. 16:373–385.
9. Jones, D.A.G., I. Sandwell, and D.J.W. Talent. 1978. The effect of soil temperature when associated with low air temperature on the cropping of early tomatoes. Acta Hort. 76:167–171.
10. Kaname, T. and T. Itagi. 1973. Effects of various air and soil temperatures on the growth and yield of tomato under glass and plastic house culture. Bul. Kanagawa Hort. Expt. Sta. 21:67–76.
11. Lewis, D. 1953. Some factors affecting flower production in the tomato. J. Hort. Sci. 28:207–219.
12. Morgan, J.V. and R. O'Haire. 1978. Heated hydroponic solutions as an energy saving technique. Acta Hort. 76:173–180.
13. Orchard, B. 1980. Solution heating for the tomato crop. Acta Hort. 98:19–28.
14. Papadopoulos, A.P. 1979. Effects of root and air temperature on physiological development and yields of tomatoes. MSc Thesis, Univ. of Guelph, Ontario, Canada.
15. Verkerk, K. 1966. Temperature response in early tomato production. Acta Hort. 4:26–31.
16. Went, F.W. 1944. Plant growth under controlled conditions. II. Thermoperiodicity in growth and fruiting of the tomato. Amer. J. Bot. 31:135–150.
17. Went, F.W. 1945. Plant growth under controlled conditions. V. The relation between age, light, variety and thermoperiodicity of tomatoes. Amer. J. Bot. 32:469–479.