Effect of Foliar Fungicide Treatment on Early Blight and Yield of Fresh Market Tomato in Ontario

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ABSTRACT

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A 2-yr field study investigated the effects of a FAST-based fungicide application regime (TOMCAST) employing chlorothalonil on early blight severity and yield of 13 fresh market tomato cultivars commercially grown in Ontario. During both years, applications of chlorothalonil decreased early blight severity, measured either as area under the disease progress curve (AUDPC) or as the last disease rating (LDR) made in late August. However, applications did not affect the yield of any cultivar, nor were fungicide–cultivar interactions detected. Cultivars differed in the extent of defoliation resulting from early blight. Disease severity (AUDPC) in the cultivar Celebrity was not affected by fungicide application. Generally, weight, number of fruit harvested, and the mean fruit weight varied significantly among cultivars.

Early blight (EB) of the foliage and fruit of tomato (*Lycopersicon esculentum* Mill.), caused by the fungal pathogen *Alternaria solani* Sorauer, occurs yearly in Ontario. Current recommendations for EB control in Ontario (3) and elsewhere rely on the use of fungicide spray programs. These programs are often based on calender systems, although some workers have attempted to use predictive schemes based on environmental conditions to make these fungicide applications more effective (21,25). In Ontario, a predictive spraying scheme known as TOMCAST (26) is widely used by the processing tomato industry and by provincial extension agents who advise fresh market tomato growers. This system uses disease severity values calculated by using daily dew periods and average temperature during these periods to time the spraying, in a manner identical to that originally developed in the FAST forecast system (21).

In Ontario, the fungicides mancozeb, chlorothalonil, and anilazine are recommended to control EB (3). However, the registration of mancozeb has been questioned recently; many Ontario processors would not accept tomatoes with mancozeb residues in 1991. Increased public concerns over pesticide use have made alternative forms of disease control desirable.

Although tomato breeding lines exist that possess resistance to EB (12,24), most commercial cultivars are susceptible. Horizontal resistance exists and may be exploited to achieve acceptable levels of control (4,5). Tomato can withstand considerable levels of defoliation without notable yield effects (31). In Canada, Basu (7) found that six of nine fresh market tomato cultivars showed no yield depression when grown without the use of fungicides to control EB. None of the cultivars studied by Basu (7) is widely grown. In order to identify fresh market cultivars with tolerance to EB, 13 commercial cultivars were studied in 1990 and 1991 for their susceptibility to EB and for the effect of the disease on yield. Disease levels, defoliation, and yields were determined in the presence or absence of a prophylactic fungicide spray regime (TOMCAST).

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MATERIALS AND METHODS

The tomato cultivars, ranging from early to late in fruiting maturity, were Ultrasweet, SummerSet, TH-318 (H.J. Heinz Co., Leamington, ON), Stokes Pak, Pilgrim, Flash (Asgrow Seed Co., Kalamazoo, MI), Summer Flavor 6000 (Abbott and Cobb Seeds Inc., Feasterville, PA), Sunny (Asgrow Seed Co., Kalamazoo, MI), Olé (Harris Moran Seed Co., Rochester, NY), Red Star VFN, Celebrity, Mountain Delight, and Mountain Pride. Unless otherwise noted, seeds were obtained from Stokes Seed Co., St. Catherines, Ontario. Transplants were produced by seeding into 128 cell Landmark plug trays filled with a soilless rooting substrate (8). Transplants were planted out approximately 28 days after seeding, on 22 May 1990 and 21 May 1991. The soil types were Bookton-Fox glaciolacustrine sands at the 1990 trial site and Wattford glaciolacustrine sands at the 1991 site (13). Cultural practices in both years were as recommended for the cultivation of tomatoes in Ontario (3).

In both years, the design was a split plot with systematic arrangement of the main-plot units (i.e., paired randomized complete blocks on contiguous parcels of land), with fungicide application as the main-plot treatment, cultivars as subplot treatments, and four replications (blocks) per main plot. Subplots consisted of 10 plants with two end-guard plants at each end of the plot. Guard rows (cultivar Mountain Pride) were grown on each side of the blocks. Plant spacing was 0.6 m within the row and 1.5 m between adjacent rows. Main plots were separated by 6.0 m. Each pair of trials covered 0.17 ha. This experimental design was adopted, rather than a simple split plot, because it allowed the use of a commercial tractor-mounted spray system for fungicide application, required only one spray-break area, and minimized the need for guard rows. Although the main-plot effects could not be evaluated directly within each year, the subplot error could be used to differentiate cultivar effects and spray treatment–cultivar interactions (9). Main-plot effects were evaluated over the two years by considering the years to be replicates.

Plots were either sprayed with the fungicide chlorothalonil (Bravo 500) at a rate of 3 L in 800 L water per hectare or left unsprayed. Fungicides were applied with a row crop boom sprayer equipped with no. 3 T-Jet nozzles, operating at a pressure of 1,660 kPa. Five fungicide applications were made in 1990 between 10 July and 30 August, and four in 1991 between 25 June and 15 August. Spray applications were timed according to the TOMCAST system by using the temperature–leaf wetness criteria developed in the FAST predictive scheme. Environmental data were collected with sensors supplied by Ridgetown College of Agricultural Technology (Ridgetown, ON), and were identical to those used by the provincial extension service. In 1990, all plots received an application of chlorpyrifos (Lorsban, 2.4 L/ha) on 27 May to control infestations of cutworm, and azinphos-methyl (Guthion 240 SC, 1.75 L/ha) on 28 June to control Colorado potato beetle. In 1991, all plots received three sprays of azinphos-methyl to control Colorado potato beetle (1.5 L/ha on 24 May, and 0.85 L/ha on 31 May and 12 July). For the assessment of EB severity, four (1990) or three (1991) plants per plot were selected at random and flagged after transplanting. Each flagged plant was evaluated for the extent of defoliation at 7-day intervals starting at the first appearance of EB in the plots. Disease severity was based on an esti-

Table 1. The effect of foliar fungicide application on yield and early blight disease severity pooled over data from 13 fresh market tomato cultivars. n = 52 for each value reported other than the means where n = 104

Year	t/ha[w]		No. fruit/ha × 10^3		Mean fruit weight (g)		AUDPC[x]		LDR[x]	
	+[y]	−	+	−	+	−	+	−	+	−
1990	86.0	91.5	470.4	508.5	183	172	104.0	152.0	9.7	14.6
1991	65.9	68.0	417.2	440.2	155	152	154.7	209.5	14.4	20.2
Mean[z]	75.9 NS	79.7	443.8 NS	474.3	168 NS	162	128.8**	180.5	12.0**	17.4

[w] Values for t/ha, no. of fruit/ha × 10^3, and mean fruit weight are the back-transformed geometric means based on analysis of the logarithms of the original data.
[x] Values for AUDPC (area under disease progress curve) and LDR (last disease rating) are the back-transformed weighted means based on analysis of the square roots of the original data.
[y] + = Chlorothalonil applied as foliar spray through season; − = no foliar fungicides applied.
[z] NS = not significantly different ($P > 0.05$) from the nonsprayed treatment; ** = significantly different ($P < 0.01$) from the nonsprayed treatment.

mation of the percentage of leaf area displaying symptoms characteristic of EB, using a whole-plant rating scheme with 10 levels ranging from 0 to 100% defoliation. The rating scale was as outlined for late blight development by James (16) with the following modifications: 0.1% = minor spotting on the lowest leaves; 1% = lower leaves with 25–50% of the area infected on one leaflet, small spots in middle or upper canopy; 5% = several leaves in lower to middle canopy with 50–100% necrotic area; 15% = two or more dead leaves in both lower and middle canopy, and infection observed on the upper canopy. Data on percent defoliation were used to determine the area under the disease progress curve (AUDPC) for each cultivar for the period ending 23 August 1990 or 21 August 1991 with the formula of Shaner and Finney (28). Data were processed with the GLM procedure of SAS (SAS Institute, Cary, NC). The last disease rating (LDR), made at the end of August in each year, was also analyzed. Artificial inoculation was unnecessary, because EB is ubiquitous at Simcoe. Diseased leaf samples were periodically collected, and isolations from lesions confirmed the presence of *A. solani.*

Table 2. The effect of foliar fungicide application on area under the disease progress curve (AUDPC) for 13 fresh market tomato cultivars in 1990 and 1991

Cultivar	AUDPC[v] 1990[w] Control[y]	1990 + Spray	1991 Control	1991 + Spray	Pooled over years[x] Control	Pooled + Spray	Mean[z]
Pilgrim	195.8	154.0	299.9	217.8	244.0	184.1	213.1 a
SummerSet	203.4	87.9	272.3	195.8	235.6	136.9	183.0 b
Flash	168.4	99.2	269.3	187.8	214.9	145.7	181.0 b
TH-318	178.7	116.8	258.9	188.3	214.6	148.1	179.9 b
Stokes Pak	175.0	127.3	202.3	172.1	188.2	145.4	166.2 bc
Red Star	140.4	106.3	213.6	164.1	174.2	132.5	152.6 cd
Olé	172.8	105.0	215.9	134.1	192.1	117.5	152.5 cd
UltraSweet	131.2	111.6	202.9	161.2	170.0	132.7	149.6 cd
Mountain Delight	135.6	109.4	170.0	123.6	157.0	117.9	136.8 de
Summer Flavor 6000	137.8	83.1	186.6	148.7	159.5	113.2	135.4 de
Sunny	135.6	101.1	175.8	121.2	154.0	109.8	131.0 de
Mountain Pride	111.6	87.9	170.0	118.3	137.8	102.0	119.2 ef
Celebrity	109.8	92.7	132.5	112.4	120.1	100.0*	109.9 f
FLSD 5%	47.9	NS	45.2	36.8			

[v] Area under the disease progress curve (AUDPC). Cultivars are ranked from greatest to least overall mean AUDPC.
[w] Values under year headings are based on nontransformed data. FLSD values for each column are based on the error associated with that main plot only; NS indicates significant cultivar effects were not detected ($P > 0.05$).
[x] Back-transformed weighted means based on analysis of the square roots of the original data. * = not significantly different ($P > 0.05$) from the nontreated control for that cultivar.
[y] Control plots received no fungicide sprays through the season; + spray plots received applications of chlorothalonil.
[z] Numbers followed by the same letter are not significantly different using Fisher's least significant difference groupings ($P = 0.05$) obtained with square root-transformed data.

In 1990, harvests were made on 29 August and 5 and 12 September. Fruit harvested from the flagged plants were either ripe or at the mature green (breaker) stage of development. In 1991, fruit were harvested on 29 July, 6, 12, 19, and 24 August, and 4 September, and were generally at the mature green stage. The number and weight of marketable fruit per plot were determined. Fruit free from visible defects or rotting and greater than 38 mm in diameter were graded as marketable. Harvest data were converted to tonnes per hectare or number of fruit per hectare before statistical analysis. Nonmarketable fruit were not included in the analysis for either year. In both years, fruit cracking and rotting were uncommon; blossom end rot was the most common cause of fruit culling, and Rhizoctonia soil rot (*Rhizoctonia solani* Kühn) was the most common fruit rot disease encountered.

Weather data were collected at the Horticultural Experiment Station in Simcoe from an automated weather station operated by the Ontario Ministry of Agriculture and Food.

RESULTS

Early blight was first detected on the oldest lower leaves in early July in both years. Often these leaves were touching the soil, suggesting that infection may have originated from soilborne inoculum (6). The disease appeared to start in both sprayed and nonsprayed main plots at about the same time, but subsequent disease progress was more rapid in the nonsprayed plots, as shown by their higher mean AUDPC ratings (Table 1). Visual assessment indicated that EB was the most important foliar disease in the plots, with other diseases not appearing until September in both years.

Measured yields, as tonnes per hectare, numbers of fruit, and average fruit weight, were higher in 1990 than in 1991; and disease, as measured by both AUDPC and LDR, was lower (Table 1). Yield data were transformed to logarithms, and disease-rating data were transformed to square roots to allow a valid analysis of variance when the experiments were pooled across years.

When AUDPC was considered within years and main-plot types (i.e., analysis as paired randomized complete block experiments), highly significant differences ($P < 0.01$) occurred among cultivars, except in the case of the 1990 fungicide-sprayed plots ($P = 0.1856$). With the appropriate within-year error term, no significant interaction was detected between spray treatment and cultivar in either 1990 ($P = 0.2257$) or 1991 ($P = 0.4033$); spraying resulted in a lower disease severity and AUDPC in both years for all cultivars. In general, the EB severity for the cultivars was consistent over years and spray-nonspray treatments. Later maturing cultivars, such as

Mountain Pride and Celebrity, showed the lowest AUDPC in both 1990 and 1991, both separately and overall (Table 2). Early maturing cultivars developed greater AUDPC values in both years and overall; the cultivars Pilgrim, SummerSet, Flash, Stokes Pak, and TH-318 were the most severely affected as measured by AUDPC (Table 2).

When the experiment was analyzed as a split-plot design, fungicide application significantly (P = 0.0088) lowered the AUDPC over the two years (Table 1). Cultivars differed significantly (P = 0.0001) in the amount of defoliation they developed, as measured by AUDPC (Table 2). When orthogonal contrasts were used to check the responses of individual cultivars to the fungicide treatment, only the AUDPC for the cultivar Celebrity was not significantly affected (P = 0.146) by fungicide application. In the remaining cultivars, the AUDPC was significantly higher for the nontreated plants than for the treated plants, and a significant interaction between spraying and cultivars for AUDPC was not detected (P = 0.2596) for the experiment as a whole.

Within years and main-plot types, LDR varied significantly with cultivar type only when the plots were not sprayed (Table 3, P = 0.001 in 1990 and P = 0.003 in 1991); sprayed plots did not show significant cultivar differences for LDR (P = 0.440 in 1990 and P = 0.081 in 1991). When LDR was analyzed with pooled data over both years (Table 3), highly significant differences (P = 0.0001) were found among cultivars for LDR; these responses were similar to their responses to EB as measured by AUDPC. Spraying also significantly lowered LDR (P = 0.0057), and all cultivars showed lower LDRs when sprayed (Table 3). A cultivar–spray interaction was not significant for LDR (P = 0.8088) for the experiment as a whole, but orthogonal contrasts found that LDR values for the cultivars Mountain Pride and Mountain Delight were not significantly affected by the spray regime (P = 0.155 and P = 0.085, respectively).

Overall yields, measured as tonnes of marketable fruit per hectare, number of marketable fruit per hectare, and mean fruit weight, were all greater in 1990 than in 1991 (Table 1). In the experiment as a whole, cultivars had a significant effect on the total tonnage, numbers, and mean weight of fruit harvested (Tables 4–6, P = 0.0001 for each parameter). For the entire experiment, nonsprayed and sprayed plots had equal yields as tonnes per hectare and as number of fruit harvested per hectare (Tables 1 and 4, P = 0.1080). Significant interactions between cultivars and the response to fungicide application were not detected for the yield parameters measured in either year, using the within-year main-plot error term (9) or the standard main-plot error term for the experiment as a whole. Yield values were similar whether or not the cultivars were sprayed (Tables 4–6). Orthogonal contrasts did not reveal differences between yields of sprayed and nonsprayed plots for any cultivar.

In 1990, independent analysis of variance for each main plot revealed no significant differences among cultivars for either total tonnes per hectare or number of fruit per hectare, with either spray regime (Tables 4 and 5). Mean fruit weight was found to vary significantly among cultivars when fungicide was applied (Table 6, P = 0.0005) but not in its absence (P = 0.1985). In 1991, however, there was a highly significant cultivar effect (P < 0.01) for all of these yield components (Tables 4–6). Both the yields (tonnes per hectare, number of fruit, and mean fruit weight) and their variances were greater in 1990 than in 1991.

Rainfall at the trial site (Table 7) was higher than the long-term average (e.g.,

Table 3. The effect of foliar fungicide application on the last disease rating (LDR) for 13 fresh market tomato cultivars in 1990 and 1991

	LDR[v]						
	1990[w]		1991		Pooled over years[x]		
Cultivar	Control[y]	+ Spray	Control	+ Spray	Control	+ Spray	Mean[z]
Pilgrim	18.7	12.9	32.4	18.9	24.1	15.5	19.6 a
TH-318	17.9	12.6	23.7	17.5	20.5	14.8	17.5 ab
SummerSet	16.5	11.6	26.3	15.7	20.1	12.5	16.1 bc
Flash	15.6	10.6	24.6	15.0	19.6	12.6	15.7 bc
UltraSweet	14.4	11.2	22.3	15.1	17.7	12.9	15.0 bcd
Stokes Pak	16.5	11.6	18.4	15.1	17.2	12.8	14.9 bcd
Olé	15.1	11.3	23.7	12.8	18.5	11.3	14.7 cd
Red Star	14.4	9.4	20.0	15.0	17.0	11.8	14.3 cd
Summer Flavor 6000	13.1	7.5	19.1	14.8	15.4	10.9	13.1 def
Mountain Delight	14.9	10.8	15.8	12.5	15.5	11.9*	12.9 def
Sunny	13.4	7.7	16.8	13.6	15.5	10.4	12.8 def
Celebrity	13.2	8.1	15.0	11.7	14.0	9.7	11.9 ef
Mountain Pride	9.4	7.5	13.5	12.4	12.0	9.7*	10.8 f
FLSD 5%	3.4	NS	8.2	NS			

[v] Last disease rating (LDR). Cultivars are ranked from greatest to least overall mean LDR.
[w] Values listed under year headings are based on nontransformed data. FLSD values for each column are based on the error associated with that main plot only; NS indicates significant cultivar effects were not detected (P > 0.05).
[x] Back-transformed weighted means based on analysis of the square roots of the original data. * = not significantly different (P > 0.05) from the nontreated control for that cultivar.
[y] Control plots received no fungicide sprays through the season; + spray plots received applications of chlorothalonil.
[z] Numbers followed by the same letter are not significantly different using Fisher's least significant difference groupings (P = 0.05) obtained with square root-transformed data.

Table 4. The effect of foliar fungicide application on the t/ha of marketable fruit harvested for 13 fresh market tomato cultivars in 1990 and 1991

	Marketable fruit t/ha[v]						
	1990[w]		1991		Pooled over years[x]		
Cultivar	Control[y]	+ Spray	Control	+ Spray	Control	+ Spray	Mean[z]
Summer Flavor 6000	143.5	92.1	78.2	88.3	98.1	89.3	93.6 a
Sunny	114.2	121.0	78.6	74.3	89.2	93.1	91.1 a
UltraSweet	95.4	110.9	86.5	88.1	89.6	92.3	90.9 a
Mountain Pride	91.8	73.3	89.7	69.1	90.3	70.0	79.5 ab
Olé	114.8	91.5	67.0	69.1	81.9	76.0	78.8 abc
Mountain Delight	77.5	67.9	76.1	82.6	76.6	73.1	74.8 bc
Celebrity	81.8	82.8	67.1	61.1	71.4	70.0	70.7 bcd
Flash	86.0	78.5	67.8	62.6	69.2	67.0	68.1 bcd
SummerSet	90.2	86.7	56.4	52.2	70.2	65.4	67.7 bcd
Red Star	86.9	77.3	62.1	56.9	71.0	64.1	67.4 bcd
Stokes Pak	83.1	76.1	59.6	57.8	67.4	63.8	65.6 cd
Pilgrim	69.2	71.7	53.9	52.0	59.9	57.9	58.9 de
TH-318	61.0	86.0	41.3	42.2	47.7	58.0	52.6 e
FLSD 5%	NS	NS	12.8	15.7			

[v] For cultivars pooled over all harvests. Cultivars are ranked from greatest to least overall mean t/ha.
[w] Values listed under year headings are based on nontransformed yield data. FLSD values for each column are based on the error associated with that main plot only; NS indicates significant cultivar effects were not detected (P > 0.05).
[x] Back-transformed geometric means based on analysis of the logarithms of the original data.
[y] Control plots received no fungicide sprays through the season; + spray plots received applications of chlorothalonil.
[z] Numbers followed by the same letter are not significantly different using Fisher's least significant difference groupings (P = 0.05) obtained with logarithm-transformed data.

1951–1980) (2) in 1990 but lower than the average in 1991. Intense rainstorms were responsible for the increased rainfall in August 1990 and July 1991. Average daily temperatures were higher in 1991 than in 1990, but temperatures both years were higher than the long-term average (Table 7) (1).

DISCUSSION

Although foliar fungicide sprays have been advocated for the control of early blight disease of tomato, there is conflicting evidence on its effects on yield. Madden et al (21) and Pennypacker et al (25) documented differences in EB severity with the use of the FAST predictive system compared to nonsprayed controls, but they did not report on yields. The results of my study are in general agreement with those of Madden et al (21) and Pennypacker et al (25) regarding a suppression of disease with the use of their FAST-based spray system. My evidence also indicates that cultivars differed in defoliation, and that both the extent and the rate of defoliation could be modified by fungicide application. One cultivar, Celebrity, appeared to be sufficiently tolerant of EB (as measured by AUDPC) under these test conditions that the use of fungicide sprays did not affect disease severity.

No evidence was found, however, that fungicide treatments improved yield, even among those cultivars which were the most defoliated by EB. Horsfall and Hueberger (14) noted that controlling EB would have little effect on yield in northeastern North America, because most of the fruit load would have developed by the time the disease becomes serious. Basu (7) reported that six of nine fresh market tomato cultivars showed no yield benefit from fungicide use and that 60% defoliation was required before losses from rotting fruit would reach 10%. Recently, Ferrandino and Elmer (11) found that Better Boy plants which had been inoculated with *Septoria lycopersici* Speg., and which were not treated with fungicides, had yields similar to noninoculated plants treated with mancozeb. Ferrandino and Elmer (11) found a nonlinear relation between the Septoria leaf spot AUDPC and yield. This is a type II relationship in the terminology of Johnson (18) and Mumford and Norton (23). Similar to the findings of Basu (7), Ferrandino and Elmer (11) also reported that the manual removal of either 25 or 50% of the leaves of Better Boy had no effect on yield (kilograms of fruit per plant) in 1988 and 1989; removal of 75% of the leaves was required to depress yield significantly. Ferrandino and Elmer (10) also found that the early yield of marketable fruit was significantly greater in diseased plots compared to spray plots, an effect also seen in my trials (R. A. Brammall, *unpublished*). Wolk et al (31) reported that

Table 5. The effect of foliar fungicide application on the number of marketable fruit harvested per hectare for 13 fresh market tomato cultivars in 1990 and 1991

	No. marketable fruit/ha[v]						
	1990[w]		1991		Pooled over years[x]		
Cultivar	Control[y]	+ Spray	Control	+ Spray	Control	+ Spray	Mean[z]
Sunny	650	676	515	455	558	539	548 a
UltraSweet	587	604	525	534	538	537	538 a
Summer Flavor 6000	560	524	495	528	524	517	520 ab
Mountain Pride	527	436	566	467	544	447	494 abc
TH--318	544	615	372	404	434	483	458 abcd
SummerSet	561	444	419	374	478	395	434 bcd
Olé	583	481	369	406	441	425	433 cd
Stokes Pak	494	452	431	359	449	394	420 cd
Flash	515	398	417	385	433	384	407 de
Mountain Delight	379	274	422	471	418	379	398 de
Celebrity	413	411	397	357	393	378	386 de
Pilgrim	417	406	384	359	394	370	382 de
Red Star	401	319	410	323	392	309	348 e
FLSD 5%	NS	NS	90	115			

[v] Number of marketable fruit/ha × 10^3 for cultivars pooled over all harvests. Cultivars are ranked from greatest to least overall mean fruit number.
[w] Values listed under year headings are based on nontransformed yield data. FLSD values for each column are based on the error associated with that main plot only; NS indicates significant cultivar effects were not detected ($P > 0.05$).
[x] Back-transformed geometric means based on analysis of the logarithms of the original data.
[y] Control plots received no fungicide sprays through the season; + spray plots received applications of chlorothalonil.
[z] Numbers followed by the same letter are not significantly different using Fisher's least significant difference groupings ($P = 0.05$) obtained with logarithm-transformed data.

Table 6. The effect of foliar fungicide application on the mean weight of marketable fruit harvested for 13 fresh market tomato cultivars in 1990 and 1991

	Mean fruit weight (g)[v]						
	1990[w]		1991		Pooled over years[x]		
Cultivar	Control[y]	+ Spray	Control	+ Spray	Control	+ Spray	Mean[z]
Red Star	216	245	152	178	181	207	193 a
Mountain Delight	186	220	181	173	183	196	190 ab
Summer Flavor 6000	258	177	157	170	201	172	186 ab
Olé	194	190	180	168	192	180	186 ab
Celebrity	197	200	169	172	183	186	184 ab
Flash	160	191	162	164	165	177	171 bc
UltraSweet	171	181	164	165	168	174	171 bc
Sunny	168	183	153	163	163	173	168 bc
Mountain Pride	174	168	158	146	166	158	162 c
Stokes Pak	163	167	140	160	153	165	158 c
Pilgrim	166	177	140	140	153	160	156 c
SummerSet	160	202	135	140	147	165	156 c
TH-318	110	138	111	105	112	121	116 d
FLSD 5%	NS	38	20	30			

[v] Mean fruit weight (g) for cultivars pooled over all harvests. Cultivars are ranked from greatest to least overall mean fruit weight.
[w] Values listed under year headings are based on nontransformed yield data. FLSD values for each column are based on the error associated with that main plot only; NS indicates significant cultivar effects were not detected ($P > 0.05$).
[x] Back-transformed geometric means based on analysis of the logarithms of the original data.
[y] Control plots received no fungicide sprays through the season; + spray plots received applications of chlorothalonil.
[z] Numbers followed by the same letter are not significantly different using Fisher's least significant difference groupings ($P = 0.05$) obtained with logarithm-transformed data.

Table 7. Weather data for tomato trial sites during the growing seasons of 1990 and 1991, at Simcoe, Ontario

	Total monthly precipitation (mm)				Average daily temperature (C)			
Month	1990	Deviation[z]	1991	Deviation	1990	Deviation	1991	Deviation
May	123.4	+ 51.9	84.2	+ 12.7	12.2	− 0.3	17.5	+ 5.0
June	61.0	− 9.6	43.3	− 27.3	19.1	+ 1.0	20.7	+ 2.6
July	89.6	+ 12.5	144.0	+ 66.9	21.4	+ 0.9	22.2	+ 1.7
August	148.1	+ 69.2	53.6	− 25.3	20.4	+ 0.9	21.2	+ 1.7
September	88.4	+ 5.9	24.6	− 57.9	15.0	− 0.5	15.6	+ 0.1
Total	510.5	+ 129.9	349.7	− 30.9				

[z] From the long-term average (1,2) for Simcoe, Ontario, during 1951–1980.

defoliation levels of 80% were required during the midseason to reduce the yield of two processing cultivars; defoliation at either 25 or 50% levels did not affect total yield, soluble solids, pH, or acidity of the fruit. MacNab and Gardner (19) and Zitter and Kodis (32) have also reported increased early ripe tomato yields in nonsprayed plots compared to sprayed controls, but total fruit yields were higher when fungicides were used.

It is possible that environmental conditions were not sufficiently conducive to disease development in either year or that the season in Ontario is short enough that disease development does not become severe enough to affect yield. Early blight is favored by warm (about 28 C), wet weather (21,22); but disease development has also been reported to be enhanced by cool temperatures (about 16 C) (27). The yields and their variance were greater in 1990 than in 1991, possibly because of more and heavier rainfall in August 1990 when fruit was maturing, especially on the mid- and late-season cultivars. The lower yield in 1991 may have been the result of the warmer, dryer conditions that year. Disease severity was greater in 1991 than in 1990, possibly because of the heavier rainfall during July when the disease first became established in the plots.

Conflicting reports on the effects on yield of fungicide sprays have been made for tomato grown in different geographic areas. Fungicides have been reported to increase tomato yields in North Carolina (29), New York (32), and Pennsylvania (19). Conversely, they have been reported not to affect total or marketable fruit yield in North Carolina (30), New York (33–35), and Pennsylvania (20). It is possible that these conflicting results reflect differences in the time when blight became established and in the rate of subsequent disease progress in these trials.

The number and yield of cull fruit was not found to be affected by spraying and was low in both trials (*unpublished*). Culling was primarily the result of blossom end rot, a physiological disorder which affects the development of young fruit (17). Reductions in fungicide use could, however, contribute to an increase in fruit rotting diseases. In studies by others, increased fruit rotting has been found when sprays are not used, caused by late blight (*Phytophthora infestans* (Mont.) de Bary) or anthracnose (*Colletotrichum coccodes* (Wallr.) S. J. Hughes) infections (20,29,30,34). Late blight disease, which affects both green and ripe fruit, occurs only under exceptional circumstances in Ontario (17), with late-season epiphytotics occurring in five of the last 46 years. However, it is not known whether the incidence of this disease would increase if reduced foliar fungicide use became a common practice. Also, nonsprayed fruit may harbor latent infections of anthracnose which could become aggressive subsequent to harvesting (15), or increased defoliation could lead to greater fruit losses from sun scalding.

Although the fungicide regime used here reduced disease progress and severity, it is possible that it did not reduce disease enough to allow detection of yield benefits. The TOMCAST system attempts to predict when sprays are required based on the temperature and leaf wetness criteria used in the FAST system (21). Even though the TOMCAST system has been widely promoted in Ontario, its effect on the yield of processing or fresh market tomatoes has not been critically evaluated or contrasted with traditional calendar spray regimes.

My evidence indicates that fungicides used according to the FAST system were not required to ensure the marketable yield of commercial fresh tomato cultivars in Ontario under conditions prevailing in 1990 and 1991.

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