Differential Sensitivity of Muskmelon and Watermelon Cultivars to Ozone-induced Foliar Injury

Michael Simini, Richard G. Snyder and James E. Simon
Department of Horticulture, Purdue University
West Lafayette, Indiana 47907

Introduction

Watermelon and muskmelon are the most important horticultural crops in southwestern Indiana, cultivated on more than 1200 and 600 hectares annually, respectively, in a five-county area of southwest Indiana (1). Recently, the commercially grown melon crops in this region have sustained considerable foliar injury caused by the air pollutant, ozone (3, 8). Ambient levels of ozone (O_3) have also caused foliar injury on O_3-sensitive bioindicator plants grown in 13 sites in southwestern Indiana (10). The O_3-induced foliar injury on muskmelons and watermelons grown in this region is distinct but similar to injury induced by nutritional imbalances (magnesium deficiency and manganese toxicity) (11).

The relationship between foliar injury, growth, and yield is not known. However, maintaining the plant canopy throughout the harvesting period is very important for the normal development of melon fruit. Chlorosis and necrosis of the adaxial leaf surface caused by O_3 may result in reduced photosynthetic capacity which may affect the set, size, and carbohydrate content of the fruit. Premature leaf abscission and leaf degradation caused by high levels of O_3 expose immature fruits to the sun, which could result in sunscald, uneven ripening, and production of unmarketable mature fruits.

Understanding the relative sensitivity of melon cultivars to air pollution stress is important in order to select cultivars for planting in areas of high O_3 pollution. Recent studies (3, 8), have shown that there is a differntial foliar response of melon cultivars to O_3. Thus, the objective of this study was to evaluate a wide range of commercially available cultivars and experimental germplasm not yet released, in order to identify O_3-tolerant muskmelon and watermelon genotypes.

Materials and Methods

This study was undertaken at the Southwest Purdue Agricultural Center (SWPAC) in Vincennes, Indiana, to determine the extent of foliar injury on muskmelon and watermelon cultivars. Each genotype was first seeded in the greenhouse, then transplanted to the field in a randomized complete block design with 3 or 4 replications as previously described (3, 8). Black plastic mulch and trickle irrigation were used, and standard cultural practices (9) were followed throughout the growing season. Ambient O_1 concentrations were monitored and recorded as previously described (8, 10).

Foliar injury was rated visually during the growing season and was based on the percentage of ozone injury (0-100%) on the leaves in each plot. It should be noted that the visual injury ratings were taken on melons that were part of the annual statewide vegetable cultivar trials, some of which were evaluated (replicated) while others were only observed (non-replicated). This accounts for the lack of consistency in the inclusion of the same set of cultivars in each year and trial.

Results

Injury appeared as a chlorosis and necrosis of the adaxial leaf surface. Most muskmelon and watermelon lines grown during 1985, 1986, and 1987 exhibited some degree of O_3-induced foliar injury. A differential response to O_3 was observed among cultivars of both melon species (Table 1). In general, watermelons exhibited more foliar injury than did muskmelons.

TABLE 1. Evaluation of Ozone-Induced Foliar Injury of Muskmelon and Watermelon Cultivars at Vincennes, Indiana, 1985, 1986, and 1987.

Cultivar	Seed Source	Visible Leaf Injury (%)[z] 1985	1986	1987
Muskmelon Cultivars[y]				
HXP 3592	HM	50 a[x]	—	8 abc
Bush Star	PS	40 a	—	—
Earlisweet	PS	20 b	17 a	14 a
Superstar	HM	17 bc	8 cde	10 abc
Goldstar	HM	17 bc	—	—
Harper Hybrid	HM	17 bc	—	0 c
Mission	AS	17 bc	—	—
Hiline	AS	—	15 ab	18 a
Laguna	AS	13 bcd	13 abc	15 a
Summet	AS	13 bcd	5 cde	11 ab
Star Trek	HM	13 bcd	7 cde	—
Alaska	PS	10 bcd	—	—
XPH 5015	AS	10 bcd	—	—
XPH 5016	AS	10 bcd	—	—
XPH 5091	AS	10 bcd	—	—
XPH 5089	AS	10 bcd	—	—
Roadrunner	PS	10 bcd	2 e	13 ab
Supermarket	HM	8 bcd	—	—
Classic	PS	8 bcd	12 bcd	—
Allstar	AS	—	8 cde	9 abc
No. 45 SJ	AS	7 cd	—	—
NCX 767	HM	7 cd	—	—
HY-Mark	PS	7 cd	—	—
Saticoy	HM	7 cd	5 cde	14 a
Aurora	AS	—	5 cde	10 abc
Top Mark	PS	3 d	7 cde	3 bc
Market Star	PS	—	3 de	9 abc
Pulsar		—	—	9 abc
Zenith	AS	—	—	11 ab
Watermelon Cultivars				
Early Star	PS	84 a	—	—
Blue Belle	AS	78 ab	—	—
XPH 957	AS	73 ab	—	—
Sundance	AS	—	57 a	—
PS19981	PS	60 abc	53 ab	62 a
Crimson Sweet	AS	55 bcd	37 abcd	58 a
XPH 5078	AS	54 bcd	—	—
XPH 5084	AS	50 bcd	—	—
AU Producer	HL	—	33 bcd	27 b
Royal Sweet	PS	35 cde	20 de	52 ab
MOX 1568	HM	32 de	43 abc	—
Oasis	HM	23 ef	33 bcd	43 ab
Jubilee	HM	23 ef	27 cde	30 b
XPH 5083	AS	17 fg	—	—
Royal Crimson	PS	17 fg	—	—
XPH 962	AS	10 fgh	—	—
Royal Windsor	PS	10 fgh	27 cde	48 ab
Iopride	HM	10 fgh	—	—
Charleston Gray 133	SS	10 fgh	—	—
Charleston Gray	AS	10 fgh	17 de	45 ab
Prince Charles	PS	5 gh	20 de	38 ab
Royal Jubilee	PS	3 h	8 e	38 ab
Madera		—	—	52 ab

[z] Rated as percent leaf area with visible injury

[y] Seed sources included: Asgrow (AS), Harris-Moran (HM), Hollar Seeds (HL), Petoseeds (PS), and Sunseed (SS).

[x] Mean separation for each crop within columns by Duncan's Multiple Range Test, 5% level.

The degree of foliar injury of muskmelon cultivars varied among years, although the year effect was not statistically analyzed (Table 1). Six of the nine cultivars had less foliar injury in 1986 than in 1985. In 1987, nine of 11 cultivars had more visual injury than in 1986, while five of nine cultivars had less injury than in 1985. The genotypes exhibiting the most O_3-induced foliar injury were 'HXP3592' and 'Bush Star' in 1985; 'Earlisweet', 'Hiline', and 'Laguna' in 1986; and 'Earlisweet', 'Hiline', 'Laguna', and 'Saticoy' in 1987. The cultivars which had greatest ozone damage in two or more years were 'Earlisweet', 'Hiline', and 'Laguna', but it should be noted that all cultivars were not evaluated every year.

Cultivars with the lowest damage ratings were 'Top Mark' in 1985, 'Roadrunner' in 1986; and 'Harper Hybrid' in 1987. Most genotypes were intermediate in foliar sensitivity to O_3.

Visual leaf injury also varied among the watermelon genotypes (Table 1). The smaller fruited (less than 8 kg avg. fruit wt.), spherical watermelon cultivars such as 'Early Star', 'Blue Belle' and 'PSI9981' were among the most sensitive cultivars to O_3-induced injury. Among the medium to large watermelon types, 'Crimson Sweet', 'Jubilee' and 'Royal Jubilee' exhibited the least amount of foliar injury. The injury ratings also varied among years. The foliar injury was higher in 1986 than in 1985 in 7 of 10 cultivars. In 1987, nine of ten cultivars had more leaf injury than in 1986, while nine of nine had more injury than in 1985. The watermelon cultivars with the most leaf injury included 'Early Star' in 1985, 'Sundance' in 1986, and both 'PS19881' and 'Crimson Sweet' in 1987. Those with the least damage were 'Royal Jubilee' in 1985 and 1986, and 'AU Producer' and 'Jubilee' in 1987.

Based upon visible leaf injury, melon genotypes could be classified according to their relative tolerance to ozone injury. The relative sensitivity of selected minor and newer genotypes were evaluated in a separate study in 1986 and 1987 and also indicate significant differential sensitivity among those evaluated (Table 2).

TABLE 2. Evaluation of Ozone-Induced Foliar Injury on New and Minor Muskmelon and Watermelon Cultivars at Vincennes, IN, 1986 and 1987.

Cultivar[z]	Seed Source	Visual Leaf Injury (%)[y]	
Muskmelons		1986	1987
Early Dawn	Harris	40	20
Earligold F_1	Hollar	23	20
Delicious 51	Harris	17	—
HSR 294	Hollar	17	—
Earlimark	Hollar	13	0
Schoon's Hard Shell	Twilley	7	5
Harvest Queen	Twilley	3	10
Pulsar	Petoseeds	3	—
XPH 5091	Asgrow	3	—
Watermelons			
Charlita Improved	NX[x]	60	85
85-5458 (NZ)	NZ	60	—
85-5453 (NZ)	NZ	50	—
Sweet Home	NZ	50	70
XPH 5084	Asgrow	30	50
Sunshade	Asgrow	20	10
Carmen F_1	Hollar	20	—
Dixie Lee	Twilley	20	45
XPH 5078	Asgrow	10	65
AllSweet	Twilley	10	50

[z] Muskmelon leaf injury based on replicated plots and watermelon leaf injury based on unreplicated plots.
[y] Rated July 22, 1986, and August 12, 1987, as percentage of leaf area with visible injury.
[x] NZ = Nickerson-Swann.

The time at which foliar injury is rated for watermelon is important. While on June 25, 1985, 'Early Star', 'Crimson Sweet', 'Jubilee', and 'Charleston Gray' had no O_3-induced foliar injury, on July 17, injury was present on all cultivars except 'Charleston Gray' (Figure 1). By August 6, a distinct differential response to O_3 was observed among

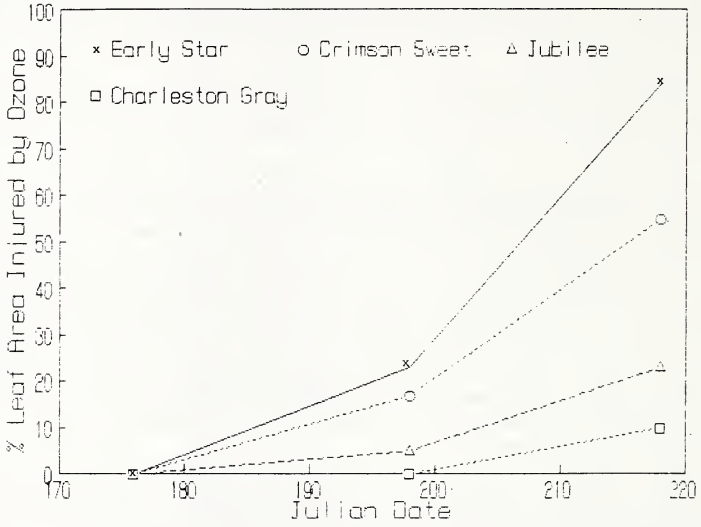

FIGURE 1. Comparison of foliar sensitivity of the 'Early Star', 'Crimson Sweet', 'Jubilee', and 'Charleston Gray' watermelon cultivars grown in Vincennes, Indiana and exposed to daily ambient O_3 concentrations of 0.062 ppm, from May 1 - August 31, 1985.

the cultivars, with 'Early Star' and 'Crimson Sweet' showing much more visual injury than the other cultivars. A similar differential response was observed on watermelons in 1986 (Figure 2), and has been reported elsewhere for muskmelon (8).

Tolerance of muskmelon and watermelon genotypes appears to be related to the date of maturity. In general, those cultivars which had the greatest percentage of mature fruit at an earlier date sustained more foliar injury than those which matured at a later date. For example, 81% of the sensitive muskmelon cultivar 'Bushstar' was harvested by August 2, 1985, while only 3% of the tolerant 'Top Mark' was harvested by this time. With watermelon, 81% of 'Early Star' and 52% of 'Crimson Sweet' were harvested by August 9, 1985. These cultivars were more sensitive to ozone than 'Royal Jubilee', of which only 4% was harvested by this date.

The location of injury on the plant is an important factor to consider in the assessment of foilar injury. In watermelon, the 'crown' leaves (older mature leaves about the main stem) had a greater percentage of leaf area injured when compared to the entire plant (Figure 3).

To assess potential differences between the standard and newer generation breeding lines, the cultivar 'Crimson Sweet' was compared to 'Royal Sweet'; 'Jubilee' to 'Royal Jubilee'; and 'Charleston Gray' to 'Prince Charles'. Some of the newly developed cultivars exhibited marked reductions in the degree of foliar breakdown compared to older standard parents from which in part they were developed. Foliar injury of 'Royal Sweet' and 'Royal Jubilee' was considerably less than 'Crimson Sweet' and 'Jubilee', (Figure

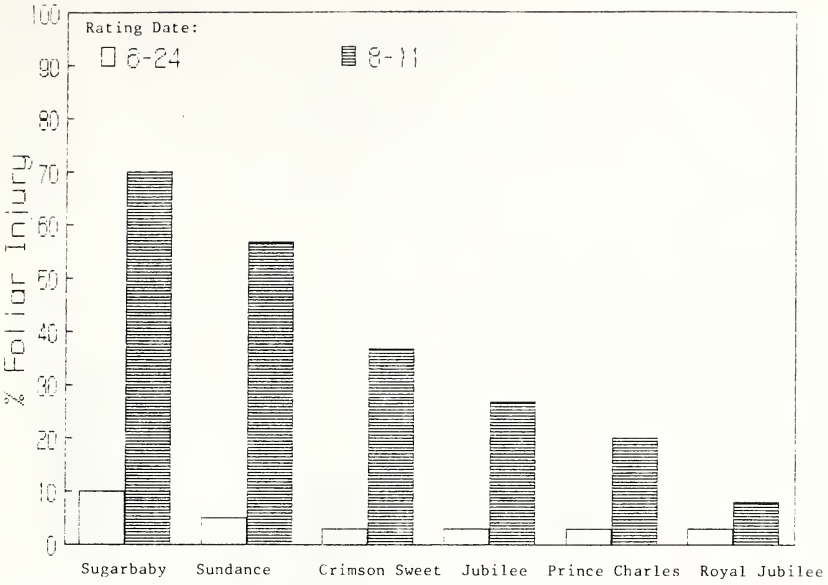

FIGURE 2. Comparison of O_3-induced foliar injury of watermelon cultivars, visually rated June 24 and August 11, 1986.

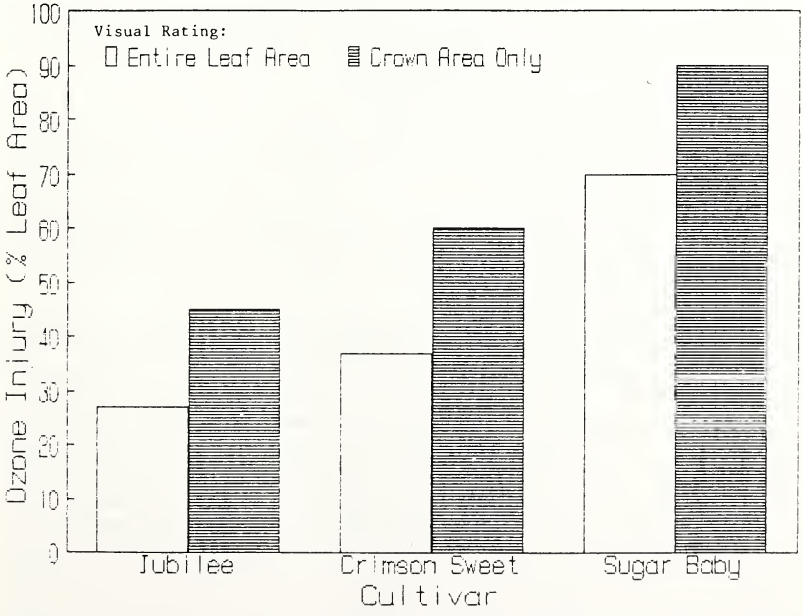

FIGURE 3. Different methods of rating ozone injury on watermelon. Vincennes, Indiana, visually rated August 11, 1986.

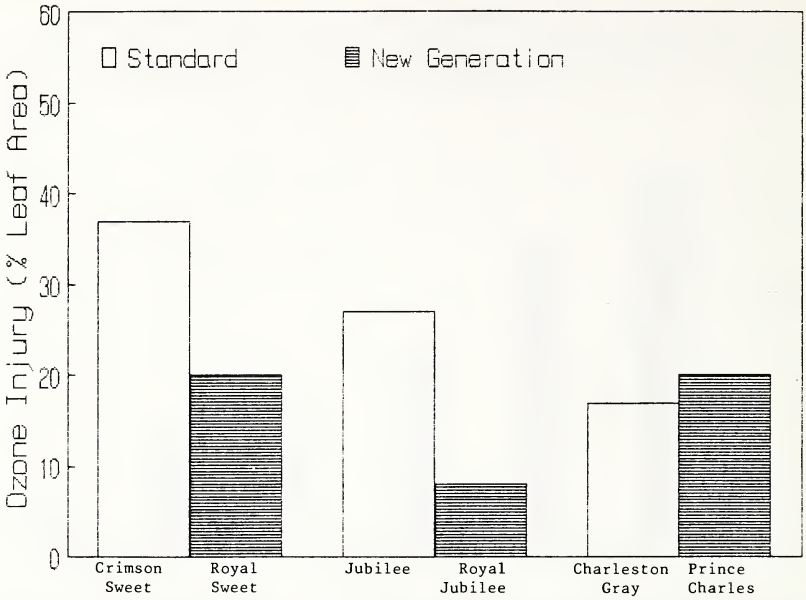

FIGURE 4. Differential sensitivity to O_3-induced foliar injury by newer generation watermelon lines. Visually rated August 11, 1986.

4). 'Prince Charles', a newer release of the 'Charleston Gray' watermelon, had approximately the same amount of foliar injury.

Discussion

This study has shown a differential sensitivity of muskmelon and watermelon cultivars to O_3-induced foliar injury and suggests possible explanations for this differential response. Differences in injury from year to year indicate that the environment affects a plant's susceptibility to O_3 stress and that seasonal O_3 concentrations vary from year to year. Cultivars must be screened over a multi-year period to determine their relative tolerance to O_3-induced foliar injury, and this criterion should be included in muskmelon and watermelon breeding programs.

The stage of development at which the melon plants sustain the most injury can be critical with respect to the effect on marketable yield. Early maturing cultivars, favored for commercial production, were more sensitive than later maturing cultivars. The watermelon cultivar 'Early Star' had the greatest increase in foliar injury (61%) between July 17 and August 6, when 80% of its fruit were harvested. The later maturing cultivars, 'Jubilee' and 'Charleston Gray', had much lower increases in the rate of visible foliar injury. Clark et. al. (2) reported similar results with potato cultivars. One possible reason for this response is that the highest concentrations of O_3 were present (10) at the time when sensitive cultivars had the greatest portion of leaves fully mature, and mature leaves are known to be most sensitive to O_3 injury (4, 5, 7). Furthermore, the rapidly maturing cultivars may have a higher metabolic rate and absorb greater amounts of ozone. A higher metabolic rate could influence both the carbohydrate and nutrient status of the leaves, particularly when the developing fruits are strong sinks for photosynthate and minerals.

The slower growing, later maturing melon cultivars appear to be less susceptible

to foliar injury and thus may be correspondingly less susceptible to yield reductions. However, total marketable yield production may not be correlated with foliar breakdown. Previous studies with other crops have shown that yield reductions may occur without visible injury (6, 7). Further investigations are necessary to determine the relationship, if any, between visible injury, foliar degradation, and yield response in melons. If a positive correlation is found between foliar injury and yield response, the use of foliar injury indices would allow for the rapid screening of melon genotypes suitable for introduction into areas with high concentrations of air pollution.

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