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Relative Sensitivity of Avocado Varieties to Photochemical Smog (Ozone) and Sulfur Dioxide

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ABSTRACT

A preliminary study was conducted to gain general information as to the sensitivity of avocado varieties (*Persea americana* L.) to the primary component of smog, ozone (O_3), and sulfur dioxide (SO_2). Varieties on both seedling 'G6' and clonal 'Borchard' rootstocks were exposed to 0, 0.1, 0.2, 0.3, or 0.4 ppm O_3 for eight hours; or 0, 0.25, 0.5, or 1.0 ppm SO_2 for 24 hours; for two days. 'Hass', 'Whitsell', and 'Gwen' were generally more sensitive than Fuerte' and 'G6'. Mexican-race cultivars tended to be less sensitive to O_3 than Guatemalan-race cultivars. Larger, older trees on 'G6' rootstocks had less injury than smaller, younger trees on 'Borchard' rootstocks. A minimum of 0.2 ppm O_3 or 0.5 ppm SO_2 was required for acute leaf injury to avocados. Ozone injury was characterized as a brown flecking on upper leaf surfaces; and SO_2 injury as large areas of brown, dead tissue through both upper and lower leaf surfaces.

INTRODUCTION

Avocados (*Persea americana* L.) are a major tree fruit crop in southern California. In recent years, bearing acreage has increased to 74,000 in 1986 from 19,000 in 1972 *(6).* During this period, value of the California crop increased to $160 million from $25 million. Nearly all of the crop is grown in San Diego, Ventura, Riverside, Santa Barbara, and Orange counties, all of which have relatively high levels of ozone (O_3), the major phytotoxic component of photochemical smog. However, sulfur dioxide (SO_2) from industrial sources could cause problems in localized areas. Both O_3 and SO_2 are also of concern in Mexican growing areas, where air pollution problems are increasing.

There has been very limited study of the effects of air pollutants on avocados. Avocado leaf tissue was reported to be relatively resistant to O_3 *(4);* a concentration of from 0.3 to 1.0 ppm was required for eight hours to produce leaf injury, with well-defined lesions manifested at 0.5 ppm. Synthetic smog including Os at 0.17 ppm severely reduced the growth of avocado seedlings that exhibited only slight injury *(7, 10),* indicating that growth and yield could be affected with few leaf symptoms. All of the previous studies were conducted under greenhouse conditions, using avocado cultivars not currently of commercial importance.

The present study was conducted to determine the relative sensitivity of commercially important avocado cultivars to O_3 and SO_2 under experimental field conditions, as a pilot project for future growth and yield studies. Exposures at acute pollutant levels were used to induce leaf injury. The range of levels included concentrations representative of high ambient pollutant episodes.

METHODS

The varieties 'Hass', Fuerte', 'Gwen', 'Whitsell', 'Reed', and 'G6' were used in this study. These varieties differed in genetical race sources: 'Reed' = 100% Guatemalan; 'Hass', 'Gwen', and 'Whitsell' = 10 to 15% Mexican, predominantly Guatemalan; Tuerte' = about 50% Mexican and 50% Guatemalan; and 'G6' = 100% Mexican. They were grafted on two types of rootstocks: (1) 'Borchard' clonal stocks grafted six months earlier and now with tops averaging 20-30 leaves, and (2) 'G6' seedling stocks grafted 15 months earlier and now with tops averaging over 100 leaves. The 15 'G6' stock trees were planted in 5 gallon pulp pots in April using UC Soil Mix II. The 15 'Borchard' stock trees were planted in black plastic sleeves in early May, again using UC Soil Mix II. The trees were kept outside until exposures began, and were fertilized and irrigated as necessary.

The air pollutant exposures were conducted in gabled chambers *(8)* in the field at the Citrus Experiment Station of the University of California, Riverside. The chambers, constructed with aluminum frames and covered with fiberglass, were 12 feet square at the base, and 13 feet high at the peak of the gable. Charcoal filtered air was blown into the chambers 24 hours per day using $^3/4$ hp blowers. Trees were placed on a gravel bed on the floor of the chambers two weeks before the exposures began.

One of the following eight treatments was assigned to each of eight chambers: filtered air controls, O_3 at 0.1, 0.2, 0.3, and 0.4 ppm; and SO_2 at 0.25, 0.5, and 1.0 ppm. The O_3 exposures were initially for eight hours per day (0800-1600) for two days, and the SO_2 exposures for 24 hours per day for two days. Little injury occurred after two days for either the 0.2 ppm O_3 or 0.25 ppm SO_2, so the exposures were continued for five and 11 days, respectively, for these treatments. There were six trees of each cultivar, three on each of the two rootstocks, except for two trees per treatment for 'Gwen' and 'Reed' on seedling rootstocks.

Ozone was generated from oxygen by an Orec ® ozonator, and monitored with a Dasibi ultraviolet ozone analyzer. Sulfur dioxide was emitted from a heated tank of liquid SO_2 and monitored with a Teco pulsed fluorescent analyzer.

The trees were evaluated for injury the day after the exposures were completed. Each leaf was rated for the presence or absence of injury. The injury per tree was calculated as the number of leaves present with injury. The varieties were compared statistically by analysis of variance (5). The results from each pollutant treatment were analyzed separately because the lower pollutant concentrations did not produce injury. The results from 'G6' and 'Borchard' rootstock trees were analyzed separately due to the difference in injury response. The cultivar injury means were separated by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Ozone-induced leaf injury was exhibited as brown flecking between veins which resulted in an apparent bronzing of upper surfaces of leaves. Even when the leaves became naturally chlorotic with age, the O_3 injury was still noticeable as brown-black dots. Symptoms of O_3 injury were similar to those previously reported for avocado *(4)* and for some other perennial species *(2),* such as grapes.

Even though the number of trees available was limited, a general trend in injury was evident among the varieties. 'Whitsell' was the most O_3 sensitive of the five on 'G6' seedling rootstocks at the lowest concentration causing injury (0.2 ppm) *(Table 1}.* It was the only variety showing damage at that concentration after 16 hours, and its leaf injury after 40 hours was significantly greater than that of all other varieties. 'Gwen' and possibly 'Hass' were injured as much as 'Whitsell' by 0.3 or 0.4 ppm for 16 hours, with slight to moderate damage. 'Reed' was a little more resistant to O_3 than 'Hass', 'Whitsell', or 'Gwen' at 0.2 ppm O_3 for 40 hours or 0.4 ppm for 16 hours. 'Fuerte' was the most ozone-resistant, with no injury at any O_3 concentration.

The grafts on 'Borchard' rootstock were more injured by O_3 than the same varieties on 'G6' *(Table 1).* This increased sensitivity was likely due to the younger stage of the 'Borchard' grafts rather than any physiological effect of the rootstock itself. All varieties except scion 'G6' showed injury at 0.2 ppm O_3 for 16 hours. Damage after 40 hours at 0.2 ppm ranged from severe ('Reed') to moderate on all varieties except for 'G6', where there was none. At 0.3 ppm O_3, even 'G6' was injured, although the percentage of injured leaves was much less than for the other cultivars. At 0.4 ppm O_3 all cultivars were .severely injured.

Thus, on both rootstocks, the varieties with the most Mexican race germ plasm, 'Fuerte' and 'G6' respectively, were the least injured by O_3.

Leaf injury from SO_2 treatment was characterized by brown necrotic areas extending through the leaves. Injury symptoms were similar to those seen on many other species *(2).* 'Whitsell' and 'Gwen' appeared to be the most SO_2 sensitive of the five varieties on 'G6' rootstocks *(Table 2).* They exhibited the most leaf injury with 0.5 ppm or 1.0 ppm SO_2 for 16 hours, and with 0.25 ppm SO_2 for 264 hours, even though there were statistically significant differences only at 1.0 ppm SO . 'Fuerte' had only a slight amount of injury at all three of these treatments. 'Hass' and 'Reed' appeared to be the most SO_2 resistant, with no more than 1% of the leaves injured for these treatments, although the results were not statistically significant.

The younger trees on 'Borchard' again were more sensitive to the air pollutant treatments than those on 'G6', although no statistical comparison was made. 'Whitsell' had the most injury at 0.5 ppm SO_2 for 48 hours *(Table 2).* 'Hass', 'Whitsell', 'Gwen', and 'Reed' all had roughly similar amounts of injury with 1.0 ppm SO_2 for 48 hours or 0.25 ppm SO_2 for 264 hours. 'G6' had comparatively little SO_2 injury, especially at 0.5 and 1.0 ppm SO_2 for 48 hours.

Table 1. Ozone Injury to Avocado Trees Growing on 'G6' or 'Borchard' Rootstocks[z].

Cultivar	Leaves injured (%)					
	O_3 (ppm) for 16 hours[y]					0.2 ppm-40 hours[y]
	0	0.1[x]	0.2	0.3	0.4	
			G6 Rootstock			
Hass	0	0	0	4 ± 4 ab	12 ± 11 ab	0 a
Whitsell	0	0	6 ± 9	7 ± 6 ab	23 ± 16 b	29 ± 15 b
Gwen	0	---[w]	0	9 ± 2 b	27 ± 2 b	0 a
Reed	0	---	0	0 ab	2 ± 3 a	7 ± 9 a
Fuerte	0	---	0	0 a	0 a	0 a
			Borchard Rootstock			
Hass	0	0	23 ± 21	80 ± 14 b	49 ± 11	34 ± 31 bc
Whitsell	0	0	3 ± 4	56 ± 32 b	66 ± 30	23 ± 5 ab
Gwen	0	0	7 ± 7	44 ± 31 ab	63 ± 32	23 ± 19 ab
Reed	0	0	23 ± 19	51 ± 12 b	73 ± 22	57 ± 15 c
G6	0	0	0	7 ± 12 a	57 ± 1	0 a

[z]Mean ± SD for three trees, except for two trees for Gwen and Reed on G6 rootstocks. Means in columns followed by different letters are significantly different at the $p<0.05$ level according to Analysis of Variance and Duncan's Multiple Range Test to compare varieties.

[y]Eight hours per day, for two days (16 hr total), or five days (40 hr total).

[x]No injury even when extended to a total of 32 hours, eight hr per day for four days.

[w]Not enough trees to include in exposure.

Table 2. Sulfur Dioxide Injury to Avocado Trees Growing on 'G6' or 'Borchard' Rootstocks[z].

Cultivar	Leaves injured (%)				
	SO_2 (ppm) for 48 hours[y]				0.25 ppm-264 hours[y]
	0	0.25	0.5	1.0	
G6 Rootstock					
Hass	0	0	0	1 ± 1 a	0 ± 1
Whitsell	0	0	1 ± 2	18 ± 6 b	9 ± 14
Gwen	0	0	7 ± 10	11 ± 14 ab	19 ± 1
Reed	0	0	1 ± 1	0 a	0
Fuerte	0	0	1 ± 2	2 ± 3 a	4 ± 4
Borchard Rootstock					
Hass	0	0	3 ± 2 a	25 ± 23	11 ± 9
Whitsell	0	0	25 ± 4 b	13 ± 3	8 ± 13
Gwen	0	0	6 ± 5 a	38 ± 33	1 ± 2
Reed	0	0	4 ± 3 a	12 ± 15	7 ± 11
G6	0	0	1 ± 2 a	5 ± 6	3 ± 6

[z] Mean ± SD for three trees, except for two trees for Gwen and Reed on G6 rootstocks. *Means in columns followed by different letters are significantly different* at the $p<0.05$ level according to Analysis of Variance and Duncan's Multiple Range Test to compare varieties.

[y] Twenty-four hr per day, for two days (48 hr total), or 11 days (264 hours total).

The most important California avocado varieties tended to be the most sensitive to air pollution. This included 'Hass', currently the most widely grown variety, and 'Whitsell' and 'Gwen', more dwarf and precocious varieties increasing in importance. It appeared that the varieties with more Mexican genes were more resistant to air pollutants. Additional research in this area is needed to verify this preliminary observation, but it points to the potential for avocado breeding to counter injury in polluted areas. The basis for the difference in air pollutant sensitivity among varieties was not studied, but could include morphological differences. The leaves of the varieties with more Mexican genes are more pubescent, which could increase surface deposition of pollutants and thus reduce the uptake of pollutants into leaves *(9).*

Finally, this study emphasized only injury symptoms from acute air pollutant exposures. No data were collected relevant to chronic effects on growth or yield of trees. Both the earlier research with avocado seedlings *(4, 7)* and current research at the University of California, Riverside, with bearing 'Valencia' orange trees indicate that fruit trees can have growth and yield effects from air pollutants without visible symptoms. Thus, the only effective way to determine chronic air pollution effects is via a large-scale study with bearing trees over several years, as is currently being done for 'Valencia' oranges (3).

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