THE EFFECTS OF AIR POLLUTANTS ON PHOTOSYNTHESIS, VEGETATIVE GROWTH, AND DEVELOPMENT OF GRAPEVINES IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

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ABSTRACT

Mature Thompson Seedless grapevines were exposed to charcoal filtered or ambient ozone concentrations in open-top chambers near Fresno, CA., during the 1987 growing season. In addition, individual leaves were exposed to ozone concentrations of 200, 400 or 600 ppb for 5 to 10 hours. No visual ozone damage was found on leaves exposed to any of the treatments. Chronic exposure to ambient ozone concentrations within the open-top chambers reduced net CO_2 assimilation rate between 5 and 14% at various times throughout the season when comparing the ambient treatment to the charcoal filtered treatment. Treatment means averaged over the four dates on which measurements were made indicated that leaf photosynthesis was reduced approximately 9% in the ambient chambers when compared to the filtered grown vines. The initial slope of a photosynthesis/intercellular CO_2 concentration response curve (termed the carboxylation efficiency) also was less for the ambient treatment when compared to the filtered treatment. Exposure of leaves to 200 ppb ozone for 5 hours had no effect on photosynthesis. However, photosynthesis was reduced approximately 50 and 80% after 5 hours for leaves exposed to 400 and 600 ppb ozone, respectively, when compared to the controls.

Generally, there were no significant decreases in vine growth parameters, bud fruitfulness or yield when comparing vines grown in the open-top chambers exposed to either filtered or ambient air. The lack of significant differences in the growth and yield of these vines probably was due to chamber effects. The amount of fruit produced by the chamber grown vines only was 50% of that produced on vines grown outside the chambers. Vines within the chambers apparently had become alternate bearing, as yields in 1987 were similar to those in 1985. Yields in 1984 and 1986 of chamber grown vines were almost double those harvested in 1985 and 1987.

Net CO_2 assimilation rates of four out of six potted grape cultivars exposed to 1.5 times the ambient ozone concentration were approximately 25% less than those grown in the charcoal filtered chambers when measured late in the growing season. The net CO_2 assimilation rate of a fifth cultivar, French Colombard, was reduced greater than 50% when making a similar comparison. The cultivar Barbera had greater rates of photosynthesis at the higher ozone concentration.

The data indicate that ambient ozone concentrations in the San Joaquin Valley of California are great enough to decrease grapevine leaf net CO_2 assimilation. However, it is uncertain whether the reduction in photosynthesis is directly responsible for the reductions in yield that previously have been measured on vines in this area. The data also indicate that the reductions in photosynthesis due to both ambient and acute concentrations of ozone are a result of a reduction in the mesophyll's capacity to fix CO_2. Lastly, cultivar may determine, in part, a vine's sensitivity to ozone.

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SUMMARY AND CONCLUSIONS

Yield in crop plants is a function of photosynthate production and the partitioning of these photosynthates to the organ of economic interest. Experiments were conducted to determine if exposure to ozone pollution affected photosynthesis or carbohydrate partitioning in grapevines.

1. Data from this study indicate that there was no significant effect of exposure to ambient ozone concentrations in the San Joaquin Valley on vegetative growth, bud fruitfulness or yield of mature Thompson Seedless grapevines during the 1987 growing season. This was despite a reduction of leaf photosynthesis on vines exposed to ambient ozone compared to the filtered treatment.

2. There were differences among the six grape cultivars examined with regards to the effects of ozone concentration at 1.5 times ambient levels for a three month period on net CO_2 assimilation. Five of the six cultivars studied had lower rates of net CO_2 assimilation at the higher ozone concentration.

3. Leaf net CO_2 assimilation rate was reduced greater than 50% when leaves were exposed to 400 ppb ozone for 5 h when compared to the control. The reduction apparently was concentration dependent rather than dose dependent because a 10 h exposure to 200 ppb ozone did not cause a decrease in net CO_2 assimilation. A threshold for acute damage to the photosynthetic apparatus of Thompson Seedless grapevines exists between 200 and 400 ppb ozone.

RECOMMENDATIONS

1. Ambient ozone pollution in the San Joaquin Valley during 1987 did not affect yield of Thompson Seedless grapevines that had been grown in open-top chambers for four years. However, leaf photosynthesis averaged over the course of the season was reduced on vines exposed to ambient ozone. Oxidant pollution at current levels should be reduced to protect grape production in the valley.

2. The effect of cultivar on vine responses to ozone demonstrated that the reduction in leaf photosynthesis varied among cultivars planted in pots. Additional research on the physiological response of these grape cultivars to ozone should be conducted on mature vines.

INTRODUCTION

A reduction in yield of grapevines exposed to ambient levels of air pollution in the San Joaquin Valley of California has been shown (Brewer and Ashcroft, 1983). At harvest, most fleshy fruits, such as grapes, are composed primarily of water and carbohydrates. Yield in fruit crops is ultimately determined by two factors: the amount of carbohydrate formed through the process of photosynthesis, and the proportion of that carbohydrate partitioned into the fruit (Patrick, 1988). A reduction in yield may be caused by a decrease in one or both of these factors.

For perennial plants, such as grapes, development of the crop occurs over two growing seasons. Fruit buds are formed during the year prior to that in which the fruit is harvested. Thus, factors that affect photosynthesis and partitioning one year may not be evident until the following year.

The effects of air pollution on photosynthesis and stomatal conductance generally have been determined under laboratory conditions with immature, potted plants for short periods of time (Hill and Littlefield, 1969, Olszyk and Tingey, 1986, Olszyk and Tibbitts, 1981). Little is known of the effects of air pollution on photosynthesis and carbohydrate partitioning of mature plants growing in the field. Inferences from the laboratory to the field are often difficult because different environmental conditions prevail in each place and because of differences in plant materials.

The main objective of this research was to examine the effects of ambient ozone pollution on photosynthesis, carbohydrate partitioning and productivity of grapevines growing under field conditions. It was anticipated that measuring the effect of air pollution on these physiological parameters would establish a data set to modify an existing grapevine growth model. The revised model would then be used to predict effects of ozone pollution on vine productivity.

MATERIALS AND METHODS

Mature Vitis vinifera L. (cv. 'Thompson Seedless') grapevines growing at the University of California, Kearney Agricultural Center in Fresno County were used in this study. These vines, previously used by Dr. Robert Brewer in a study funded by the Air Resources Board (contract #A5-085-33), had been growing in open-top chambers for 3 years. Cultural practices were similar to those used for the production of raisin grapes (Winkler et al., 1974). Treatments were imposed by exposing entire vines in open-top chambers to (1) ambient air or (2) charcoal filtered air. The design of these chambers has been previously described (Brewer and Ashcroft, 1983). Vines growing in the same vineyard but outside the chambers also were examined to determine chamber effects. Each treatment consisted of four, 3 vine replicates.

Vines were dormant pruned to an excess of canes (6 to 8 canes, 15 nodes in length). Cluster number per vine was counted just prior to bloom in April. Shoot lengths were measured monthly beginning in May, continuing until August when it became necessary to shoot trim the vines in order to facilitate air flow through the vine's canopy within the chambers. Shoots and canes were harvested in July and January, respectively, for analysis of non-structural carbohydrates.

During leaf abscission in the fall, leaves that had dropped to the ground in the chambers were collected, dried, and weighed as a measure of the rate of leaf fall. It was not possible to quantitatively measure leaf fall for vines outside the chambers.

Berry samples were taken throughout the season for fruit size and soluble solids measurements. Brix (or soluble solids, a measure of berry sugar concentration) was measured with an American Optical model 10450 temperature compensated refractometer on extracted juice.

Cuttings of Thompson Seedless, Flame seedless, Chenin Blanc, French Colombard, Barbera, and Carignane were planted in a 2:2:1-peat:perlite:sand mixture in 10 l pots in early May. About 15 g 20-20-20 + micronutrients Osmocote slow release fertilizer (Sierra Chemical) was applied to each pot after planting, with exception of the Thompson Seedless vines. All vines were trained to a single shoot. The potted vines were grown in open-top chambers, previously described by Brewer (1986) and exposed to charcoal filtered air, ambient air or ambient air to which ozone was added to give about 1.5 times ambient ozone concentration.

The potted Thompson Seedless vines were given 500 ml of a complete nutrient solution containing either 3 or 8 mmol nitrogen, 2x per week. Visual differences between the nitrogen treatments were observable after 6 weeks.

Leaf net CO_2 assimilation was measured in an open system similar to that described by Williams (1985) and Williams and Smith (1985). Briefly, the cuvette to measure leaf photosynthesis at ambient conditions consisted of a cylindrical piece of Plexiglas sealed at one end, with a small fan mounted inside to minimize boundary layer resistance. The cuvette is constructed such that once it is clamped onto a leaf, the upper leaf surface is still exposed to the ambient environment. Heat buildup within the cuvette during measurement is less than 2°C. The chamber for steady state measurements of net CO_2 assimilation is a rectangular plexiglas chamber with a finned aluminum heat sink forming the bottom. Water is circulated along the lower side of the heat sink from a circulating water bath to control the temperature within the chamber at 30°C. This chamber also contains a fan to thoroughly mix the air and to minimize boundary layer resistance.

Air was drawn through a 50 l damping vessel, and passed through the cuvettes at a flow rate of 150 l/h. The damping vessel was used to depress oscillations of ambient CO_2 partial pressure. Flow rate was controlled by mass flow controllers (Tylan Corp.). Measurements were taken using air from the same environment to which the vines were exposed. CO_2 concentration was measured with an ADC MKIII infrared gas analyzer. Water vapor entering and leaving the cuvettes was measured with thin film capacitor type humidity sensors (Weathertronics Model 5121). Leaf temperature was monitored by copper constantan thermocouples pressed to the bottom surface of the leaf. Leaf CO_2 assimilation rate, stomatal conductance, and intercellular CO_2 concentration were calculated according to von Caemmerer and Farquhar (1981). Areas of measured leaves were determined using a LI-COR 3100 area meter.

Soluble carbohydrates were analyzed by high pressure liquid chromatography with methods adapted from McBee and Maness (1982). Plant materials were dried at 78°C in a forced air oven. Samples were ground to pass a 40 mesh screen in a rotary mill. Subsamples (100 mg) of ground tissue were extracted for 1 h in 5 ml 80% ethanol at 54°C. Solids were then removed with a swinnex filter. The pH of the filtrate was adjusted to 7 with 0.1 N KOH and 400 mg ion exchange resin were added and the samples shaken for 1 h. The ion exchange resin was removed by filtration and the samples were taken to dryness at 54°C. The samples were resuspended in 3 ml water and injected into a Beckman Model 330 isocratic HPLC. Soluble sugars were separated with an Altex μ-spherogel column and detected with an Altex model 156 refractive index detector. Peaks were integrated with a Hewlett-Packard 3390A reporting integrator.

The solids remaining from the initial filtration were resuspended in water and autoclaved for 30 minutes to solubilize the starch. The pH was adjusted to 5 with 0.2 N phosphoric acid and 23 units amyloglucosidase (Sigma) were added. Samples were incubated for 2 h at 54°C after which the pH was adjusted to 7 and 400 mg ion exchange resin were added. After shaking for 30 min the samples were filtered and taken to dryness at 54°C. Determination of the insoluble sugar fraction was as described above.

The experiment was designed as a randomized complete block. Data collected only once during the growing season were analyzed with a standard randomized complete block ANOVA. The effect of ozone on grape cultivar was analyzed as a two way factorial (See Appendix 2). Measurements taken on multiple dates were analyzed on a date by date basis using the above standard ANOVA unless stated otherwise (See Appendix 2). The F-tests were considered significant if $P \leq 0.05$. Treatment means were separated by Duncan's Multiple range test at the 5% level.

RESULTS AND DISCUSSION

The daily mean ozone concentration during the period from May through October, 1987, averaged 45 ppb (Table 1). The mean daily maximum for each month and the one hour monthly maximum were slightly less than previous years in which these grapevines were used in an ARB funded study by Dr. Brewer. It is interesting to note that the averages for the month of July generally were less than the other five months. It was anticipated that this month would have had greater ozone concentrations. It also should be pointed out that ambient temperatures for July, 1987, also were lower than the normal thirty year average for this location.

There were no significant differences in rates of net CO_2 assimilation (A) between vines grown within the filtered or ambient air chambers except for June 25 (Table 2). However, the seasonal average for leaf photosynthesis of vines grown in the filtered chambers was approximately 9% greater than that of vines grown in the ambient chambers. Leaves on vines growing outside the chambers had significantly lower rates of leaf photosynthesis compared to those within the chambers on three out of the four dates. Figure 1 shows that there was no significant effect of any of the imposed treatments on carboxylation efficiency (initial slope of an A/c_i curve). However, the trend was for greater carboxylation efficiency for leaves from the filtered environment than for those exposed to ambient ozone concentrations. Carboxylation efficiency is a measure of the ease with which CO_2 is incorporated into carbon containing compounds in the mesophyll cells of leaves. It is a combination of the efficiencies of CO_2 crossing the mesophyll cell walls, chloroplast envelope and its incorporation into sugars. It has both physical and biochemical components. The magnitude of reductions in grape leaf photosynthesis and carboxylation efficiency as affected by ambient ozone concentrations is similar to that measured on other plant species (Lehnherr et al., 1987; Reich et al., 1987; Reich et al., 1986; Reich, 1983).

Vegetative growth of vines within the filtered and ambient open-top chambers were similar. Shoot length was not affected by any of the treatments (Table 3). However, shoot length always was less on vines growing outside of the chambers. This same pattern was found when individual shoots were removed and dissected (Table 4). No significant differences among the treatments were found for any parameter measured. The lack of difference in shoot growth parameters is reflected in the lack of significant differences in pruning weights among treatments (Table 5).

There was no apparent effect of ambient ozone exposure on fresh berry weight (Table 6) or berry sugar accumulation (Table 7) between the two treatments grown within the chambers. At harvest, there were no differences found in cluster number per vine, yield or weight per cluster for vines exposed to ambient or filtered air (Table 8).

Yield in 1987 of vines grown within the open-top chambers were approximately 50% the yield of vines outside the chambers in the same vineyard. The difference in yield between inside and outside explains the differences in fruit maturity (sugar accumulation) when comparing the two. There were no significant differences in vegetative growth among treatments, therefore, the vines in all treatments had the same leaf area (which can be designated as the source of sugar needed for growth within the vine) and probably produced the same amount of photosynthate. However, since the vines on the outside had more clusters (designated as a sink for sugars), sugar accumulation was delayed for these vines because the sink was much larger. Alternatively, since the sink (clusters) of the vines within the chambers was less, sugar accumulation in the fruit of these vines proceeded more rapidly and thus were ready for harvest earlier.

The average combined yields of vines grown within the ambient and filtered chambers in 1984, 1985, 1986, and 1987 were 20.7, 12.8, 17.6, and 11.5 kg/vine, respectively. Vines grown outside the chambers averaged 20.7, 19.9, 17.4, and 21.4 kg/vine, respectively, during the same years. It appears that vines within the chambers have come into a pattern of alternate bearing (i.e. a large crop one year and a small one the next). Alternate bearing of vines grown in open-top chambers had not previously been measured (Brewer and Ashcroft, 1893; Musselman et al., 1978). Alternate bearing is a problem associated with the production of some perennial crops (most notable crop in California is pistachios). The cause of alternate bearing within these species is unknown, however, some speculate that carbohydrate or nitrogen nutrition is involved. Regardless, the vines within the chambers appear to be in an alternate pattern of fruit production while vegetative growth is unaffected. This may help explain why there may be a difference in the rate of leaf photosynthesis between the two treatments within the open-top chambers, but no differences in yield. Vines within the chambers have an ample amount of leaf area for the amount of crop they have. Therefore, small, but significant differences in leaf photosynthesis (or sugar production) over the growing season are masked by more leaf area than necessary to mature a small crop. It would have been interesting to have conducted this study in 1986 or 1988 and taken similar measurements.

After fruit harvest, leaves that had fallen from the vines were collected, dried, and weighed. When examined on a date by date basis or as the rate of leaf fall, there were no differences in leaf fall for vines exposed to ambient or filtered air (Table 9). It was not possible to measure leaf fall on vines outside the chambers. If ozone had induced premature leaf senescence leaf fall should have occurred earlier for vines exposed to ambient air. Early leaf senescence has been shown to limit carbohydrate accumulation and growth in perennial crops (Nelson and Isebrands, 1983).

Subsamples of canes and roots of vines from this study were analyzed for non-structural carbohydrates during the dormant season. Although there were significant differences between the treatments for cane carbohydrates (Table 10) the differences were not consistent with the rates of photosynthesis among treatments during the season (Table 2). Roots are the main storage organ in vines for carbohydrates and nitrogen (L.E. Williams, unpublished data). While there were no significant differences between treatments for root carbohydrates the relative differences were similar to relative differences in seasonal leaf photosynthesis between the two (Table 2). This small reduction in root carbohydrates may prove important for long-lived perennial crops.

Due to limited space within the open-top chambers used for the potted vine study, the effect of nitrogen on a vine's response to ozone was reduced to two nitrogen treatments. Thompson Seedless vines were watered with a nutrient solution containing either 3 or 8 mmol nitrogen. The rates of leaf photosynthesis of vines watered with 3 mmol N were similar regardless whether vines were grown in filtered air chambers or chambers supplemented with ozone at concentrations of 1.5 times ambient (data not shown). These results indicated that under severe N deficiency, ozone was secondary in affecting the rate of photosynthesis. Results for Thompson vines receiving 8 mmol N are shown in Table 11 and will be discussed in the context of varietal response to ozone.

Potted vines of eight different cultivars of V. vinifera were fumigated for three months at a concentration approximately equal to 1.5 times ambient ozone. Leaf photosynthesis rates of vines when averaged over all cultivars were significantly reduced 18% when comparing the high ozone treatment with the charcoal filtered treatment. The rate of leaf photosynthesis for French Colombard was reduced by greater than 50% when a comparison between the two treatments were made. Barbera vines had greater rates of net CO_2 assimilation at the higher ozone treatment than when grown in the filtered chambers. It is unknown why this anomalous result was found.

Genetic resistance to ozone has been demonstrated for various crop species. The sensitivity of grape cultivars to oxidant stipple injury (foliar injury caused primarily by ozone) also has been demonstrated (Musselman and Melious, 1984; Richards et al., 1958). The V. vinifera cultivars assessed in New York for oxidant stipple injury varied in their susceptibility, but injury ratings among cultivars were not significantly different (Musselman and Melious, 1984). In this study, the rate of leaf net CO_2 assimilation was reduced in 5 out of 6 cultivars at the high ozone concentration, with reductions in photosynthesis from 19 to 57%. Some of the reductions were significant, others were not. The data here do indicate that the major cultivars grown in the San Joaquin Valley vary in their response to ozone.

Acute exposure to high concentrations of O_3 adversely affected leaf photosynthesis (Fig. 2a). Net CO_2 assimilation of control leaves reached a maximum of about 14.5 μmol m^{-2} s^{-1} but declined to a minimum of 10 μmol m^{-2} s^{-1} five hours after the leaves were placed in the cuvettes. Leaves exposed to 200 ppb O_3 for 5 h had rates of net CO_2 assimilation which were not significantly different from the controls throughout the measurement period. Net CO_2 assimilation rates declined throughout the fumigation for leaves exposed to 600 ppb O_3. They also had significantly lower rates of net CO_2 assimilation when compared to the control leaves as early as 90 min after the initial fumigation. Leaves exposed to 400 ppb O_3 had rates of net CO_2 assimilation intermediate to those reported above for the controls and the 600 ppb O_3 treatment. After 5 h of fumigation, photosynthesis of the 400 and 600 ppb O_3 treatments was 53 and 20%, respectively, of that for the control leaves. No visual symptoms of O_3 damage were observed on treated leaves the day following treatments.

To separate the effects of ozone dose vs. concentration leaves were exposed to 200 ppb O_3 for 5 h on two consecutive days (Fig. 3). On day one an unfumigated control was included and on day two this leaf was exposed to 200 ppb for 5 h. The dose received by exposure to 200 ppb O_3 for 10 h was equivalent to that received by exposure to 400 ppb O_3 for 5 h (Fig. 2). No significant differences in photosynthesis were found among leaves exposed to 200 ppb O_3 for 5 or 5 + 5 h or the controls (Fig. 3). However, as previously stated, leaves exposed to 400 ppb O_3 showed a significant decrease in net CO_2 assimilation after 3 h of exposure (Fig. 2).

Acute exposure to high concentrations of O_3 clearly lead to a reduction in net CO_2 assimilation and stomatal conductance of grapevines in this study (Fig. 2). This is consistent with the results of other research (Tingey and Taylor, 1982). The reduction in leaf photosynthesis after exposure to acute levels of O_3 has been attributed to ozone's effect on stomatal conductance (Heath, 1980; Hill and Littlefield, 1969). There was a significant positive correlation ($r = 0.95$) between photosynthesis and stomatal conductance for the 400 and 600 ppb treatments in the present study. This may indicate that the decrease in each parameter has a common cause. However, intercellular CO_2 partial pressure did not vary during the fumigation period or among treatments. A reduction in stomatal conductance without a concomitant decrease in net CO_2 assimilation would have resulted in a decrease in intercellular CO_2 partial pressure. It has been reported that stomates will adjust to maintain the intercellular CO_2 partial pressure constant when the capacity of the mesophyll to fix CO_2 is altered (Ramos and Hall, 1982) or environmental conditions are changed (Mott, 1988). Temple (1986) suggested the same thing occurred when cotton had been exposed to O_3. This does not, however, rule out a direct effect of ozone on stomatal conductance of other plant species (Olszyk and Tibbitts, 1981).

The greater decrease of photosynthesis for leaves exposed to 400 ppb for 5 h (Fig. 2) than for leaves exposed to 200 ppb for a total of 10 h over two days (Fig. 3) indicates that the reduction in photosynthesis of grapevine by acute O_3 treatment is primarily concentration dependent and secondarily dose dependent. There may be a threshold O_3 concentration which must be exceeded before acute damage will occur. This may be the result of the plant's ability to detoxify the metabolite responsible for the decrease in physiological activity. Such a system has been reported for the differing sensitivity of two pea cultivars of SO_2 (Alscher et al., 1987). This research indicates that the O_3 threshold for Thompson Seedless grapevines is greater than 200 ppb.

It is unfortunate that fruit yield of vines grown within the open top chambers were considerably less than the outside vines or from the previous growing season. It was hoped that results from this study would provide a data set that would establish the effects of ambient pollution on vine growth and carbon assimilation. These variables would then be incorporated into an existing vine growth model and used to assess the effects of pollution on vine growth and yield. The conflicting results obtained in this study, to include the lack of effect of ambient pollution on vegetative and reproductive growth of Thompson Seedless grapevines in 1987, precludes the use of this data for such purposes. Future studies assessing the affects of pollution in the San Joaquin Valley on vine or tree growth may provide useful information for incorporation into plant models at that time.

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Table 1. The daily mean and mean daily maximum per month and maximum oxone concentrations from May through October, 1987, at the University of California, Kearney Agricultural Center, near Fresno, California.

Month[y]	Daily Mean	Daily[z] 7-h Mean	Mean Daily Maximum	Monthly Maximum	# Hours/month greater than 100 ppb
	(ppb)				- h -
May	45	81	77	124	9
June	52	87	94	178	59
July	43	75	81	122	25
August	46	88	96	174	60
Sept	46	88	104	161	77
Oct	40	73	86	165	54

[y] Data calculated from information provided by Mr. Bill House, Fresno Air Quality District (See Appendix 1). Ozone was measured at a monitoring station on the Kearney Agricultural Center premises.

[z] Mean daily 7-hour (1000 to 1700 h PDT) concentrations of O_3.

Table 2. Response of leaf net CO_2 assimilation rate, measured four times during the 1987 growing season of mature field grown Thompson Seedless grapevines given different levels of chronic ozone exposure.[x,y]

Treatment	5 May	25 June	7 Aug	21 Sept	Overall Treatment Means
			(μmol CO_2 m^{-2} s^{-1})		
Filtered	20.2 (1.2)	17.5 (0.8)	14.5 (0.3)	7.6 (0.6)	15.0
Ambient	19.2 (1.2)	15.1 (0.8)	13.7 (0.9)	6.9 (0.4)	13.7
Outside	18.9 (1.5)	11.7 (0.1)	11.7 (0.5)	3.7 (0.6)	11.5

[x]Dates of measurement, 5 May, 25 June, 7 Aug and 21 Sept, represent approximate dates of bloom, verasion (berry softening), rapid fruit development (sugar accumulation) and post harvest, respectively.

[y]The data were analyzed on a date by date basis. ANOVA table found in Appendix 2. Overall treatment means not analyzed due to uneven number of replicates on the four measurement dates. n = 6 individual leaves on each date except on 25 June where n = 3. Values in parentheses represent standard error of the mean.

Table 3. The effect of chronic ozone exposure of Thompson Seedless grapevines on shoot growth.

Treatment[y]	14 May	15 June	7 July	30 July[z]
		Average shoot length		
		---------------------- (cm) ----------------------		
Filtered	135	175	171	133
Ambient	150	177	187	156
Outside	98	118	119	110

[y] There were no significant differences among treataments. Four shoots from each of 12 individual vines were used for data collection.

[z] Measurements were made after shoots had been trimmed.

Table 4. The effect of chronic ozone exposure on shoot length, dry weight partitioning and leaf area of Thompson Seedless grapevines.[z]

Treatment	Shoot Length	Nodes/ Shoot	Lateral shoots greater than 4 nodes	Leaf Area Per Shoot	Leaf Dry Weight	Stem Dry Weight	Inter-node Length
	(cm)	(#)	(#/shoot)	(cm^2)	(g)	(g)	(cm)
Filtered	325 (47)	40 (4)	4.7 (2.6)	7378 (1491)	44 (9)	67 (16)	8.1 (0.4)
Ambient	410 (43)	43 (4)	1.3 (0.4)	7070 (1013)	40 (4)	69 (10)	9.5 (0.8)
Outside	282 (31)	37 (3)	0.8 (0.3)	5618 (637)	37 (4)	51 (7)	7.6 (0.5)

[z] Data were collected on 10 July 1987. There were no significant differences among treatments for any growth parameter except for shoot length ($\underline{P}$ <0.05). Values in parentheses represent the standard error of the mean. The data were collected using an individual shoot from each of 12 vines.

Table 5. The effect of chronic ozone exposure on pruning weights of Thompson Seedless grapevines.

Treatment[z]	Pruning Weight
	(kg/vine)
Filtered	2.5
Ambient	2.5
Outside	2.3

[z] Vines were pruned 5 January 1988. Prunings represent vegetative growth of the 1987 growing season. There were no significant differences among treatments. n = 12 individual vines.

Table 6. The effect of chronic ozone exposure of Thompson Seedless grapevines on berry size.

Treatment	8 June	8 July	28 July	10 Aug
	------------------- g/50 berries -------------------			
Filtered	41.4 a	60.3 a	66.7 a	70.4 a
Ambient	39.5 ab	60.5 a	67.5 a	78.6 a
Outside	33.9 b	42.8 b	61.6 a	73.4 a

[z] Mean separation within columns by Duncan's Multiple Range test at the 5% level ($\underline{P} < 0.05$ and < 0.01 for 8 June and 8 July, respectively).

Table 7. The effect of chronic ozone exposure on soluble solids (Brix) of berries from Thompson Seedless grapevines.

Treatment	8 July	28 July	10 Aug
		°Brix	
Filtered	16.9 a[z]	22.3 a	23.1 a
Ambient	17.4 a	22.3 a	23.2 a
Outside	11.2 b	17.2 b	18.9 b

[z] Mean separation within columns by Duncan's Multiple Range test at the 5% level ($\underline{P} < 0.001$ for all dates). n = 4.

Table 8. The effect of chronic ozone exposure on cluster number and yield of Thompson Seedless grapevines.[y]

Treatment	Cluster No./vine	Total Yield/ Vine	Fresh Weight Per Cluster
		(kg)	(g)
Filtered	27.9 a[z]	11.2 a	419 a
Ambient	26.8 a	11.8 a	439 a
Outside	49.8 b	21.4 b	439 a

[y] Harvest date for the filtered and ambient air treatments was 12 August 1987. Harvest date for outside vines was 4 September 1987.

[z] Mean separation within columns by Duncan's Multiple Range test at the 5% level ($P < 0.01$ for effects of treatment on cluster number and yield). $n = 12$.

Table 9. Effect of chronic ozone exposure of Thompson Seedless grapevines on leaf fall.

Treatment[z]	Leaf Fall (% of total) 5 Nov	25 Nov	2 Dec	11 Dec
Filtered	7	27	11	55
Ambient	9	34	10	47

[z] Leaves were collected on the dates indicated and dried. Data are expressed as the percent of the combined total dry weight for all four harvest dates. Total dry weight of leaves that fell from vines in the filtered and ambient chambers were 2245 and 2900 g/chamber, respectively. Data were collected during 1987 at the Kearney Agricultural Center, Parlier, California. There were no significant differences between treatments. n = 4 individual open top chambers, three vines in each chamber.

Table 10. Carbohydrate concentrations in canes and roots of vines exposed to different concentrations of ozone during the 1987 growing season.

Treatment	Total Soluble Sugars	Starch	Total Nonstructural Carbohydrates
		CANES[x]	
	---------- (% dry wt) ----------		
Filtered	5.5 a	1.4 a	6.9 a
Ambient	6.0 ab	2.5 a	8.5 b
Outside	7.0 b	2.1 a	9.1 b
		ROOTS[y]	
Filtered	2.5	16	18.5
Ambient	2.2	15	17.1

[x] Total soluble sugars represent glucose, fructose and sucrose. Mean separation within columns by Duncan's Multiple Range test at the 5% level ($P < 0.05$ for total sugars and carbohydrates). Vines were sampled 5 January 1988. n = 6 individual vines.

[y] There were no significant differences between treatments. n = 4 individual vines.

Table 11. The effect of chronic ozone exposure of six *Vitis vinifera* cultivars on leaf photosynthesis measured on 24 September 1987.[x]

Treatment	Barbera	Carignane	Chenin Blanc	Flame Seedless	French Colombard	Thompson Seedless	Treatment Means
				Cultivar			
				($\mu mol\ CO_2\ m^{-2}\ s^{-1}$)			
Filtered	5.3 a	6.4 a	7.7 a	8.3 a	8.8 a	9.4 a	7.6 a
1.5x Ambient	8.9 b	4.9 a	5.8 a	5.9 a	3.8 b	7.9 a	6.2 b

[x] Treatments are charcoal filtered air and air to which ozone was added to equal 1.5 times ambient ozone. The data were analyzed as a two way factorial. ANOVA table found in Appendix 2. Mean separation within a column by Duncan's Multiple Range test at the 5% level. n = 4 individual leaves.

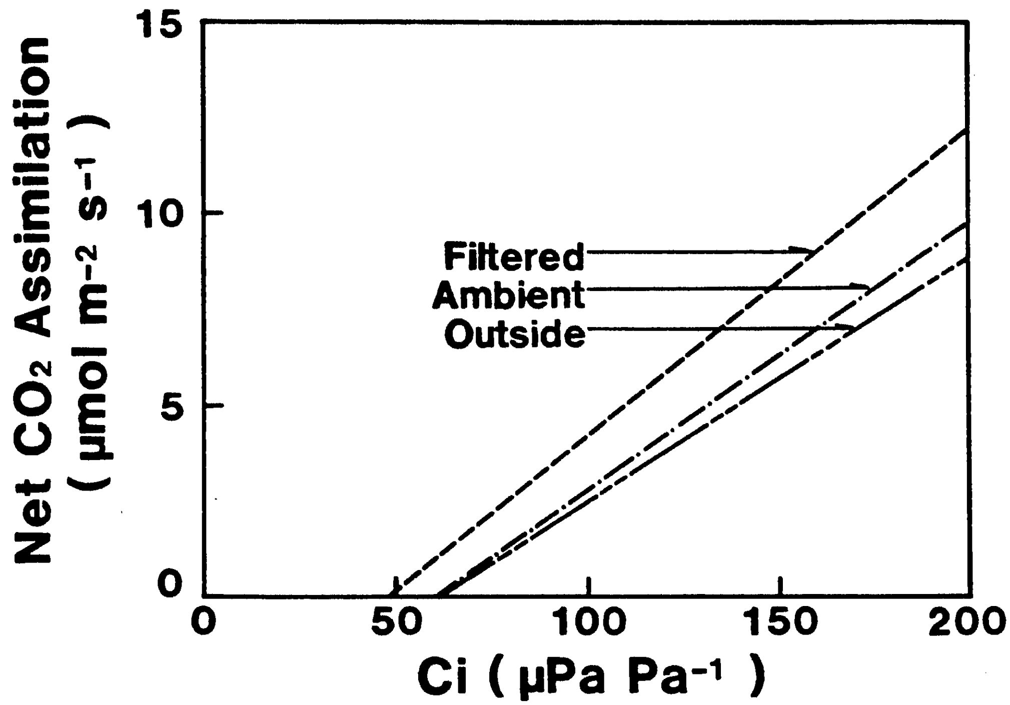

Figure 1. The effect of chronic ozone exposure on the relationship between net CO_2 assimilation (A) and intercellular CO_2 partial pressures of Thompson Seedless leaves. Linear regression analysis of the three treatments resulted in coefficient of determination values (r^2) greater than 0.90 for each of the treatments. The slopes of the lines are: filtered - 0.079, ambient - 0.069, outside - 0.065. n = 6.

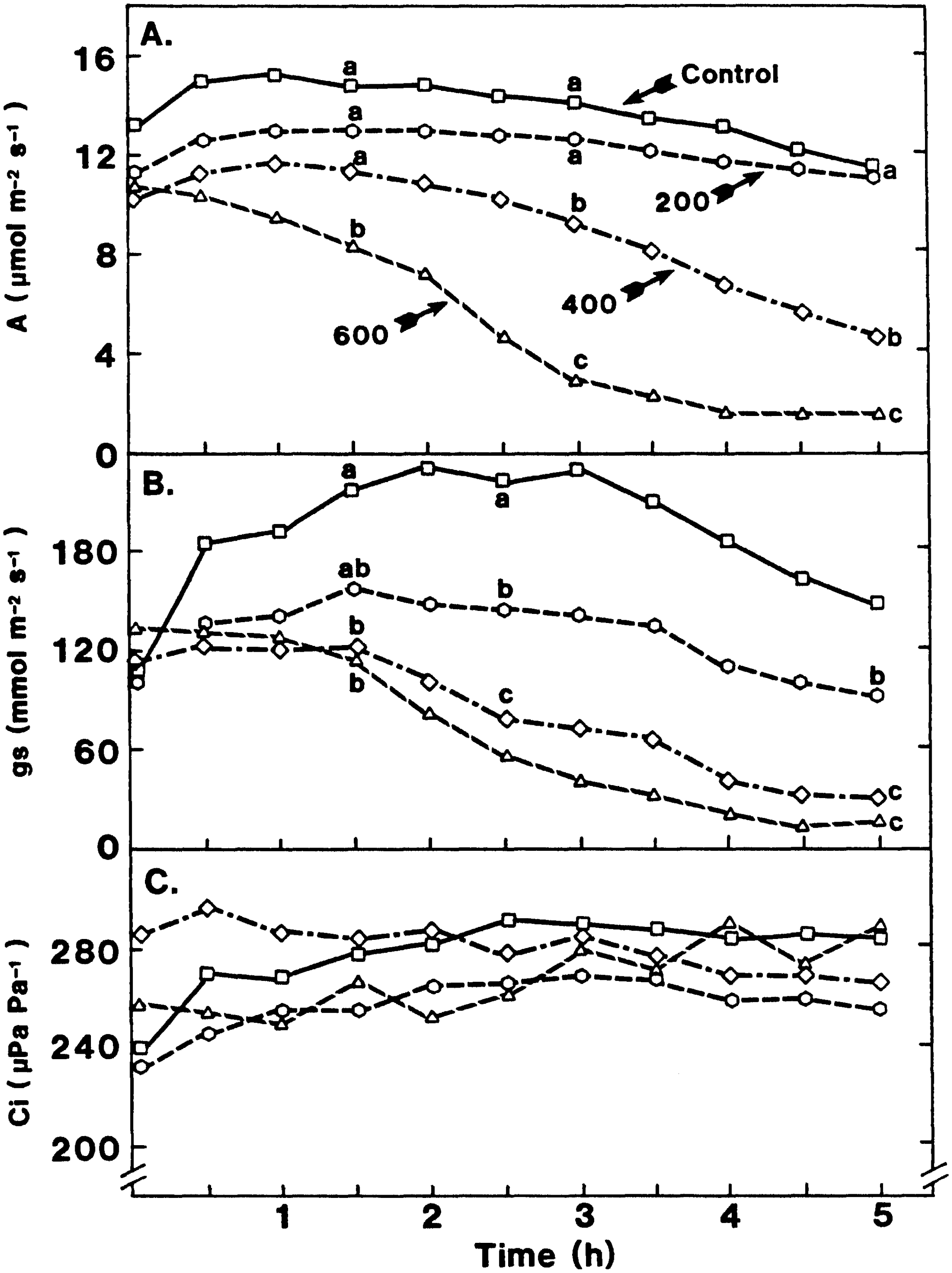

Figure 2. The response of A, g_s and c_i of leaves of mature fieldgrown Thompson Seedless grapevine to acute O_3 exposure. Measurements were conducted between September 27 and October 9, 1987. Within each time, points followed by different letters are significantly different at the 5% level. Leaves were exposed to charcoal filtered air (control), 200, 400 or 600 ppb ozone in air.

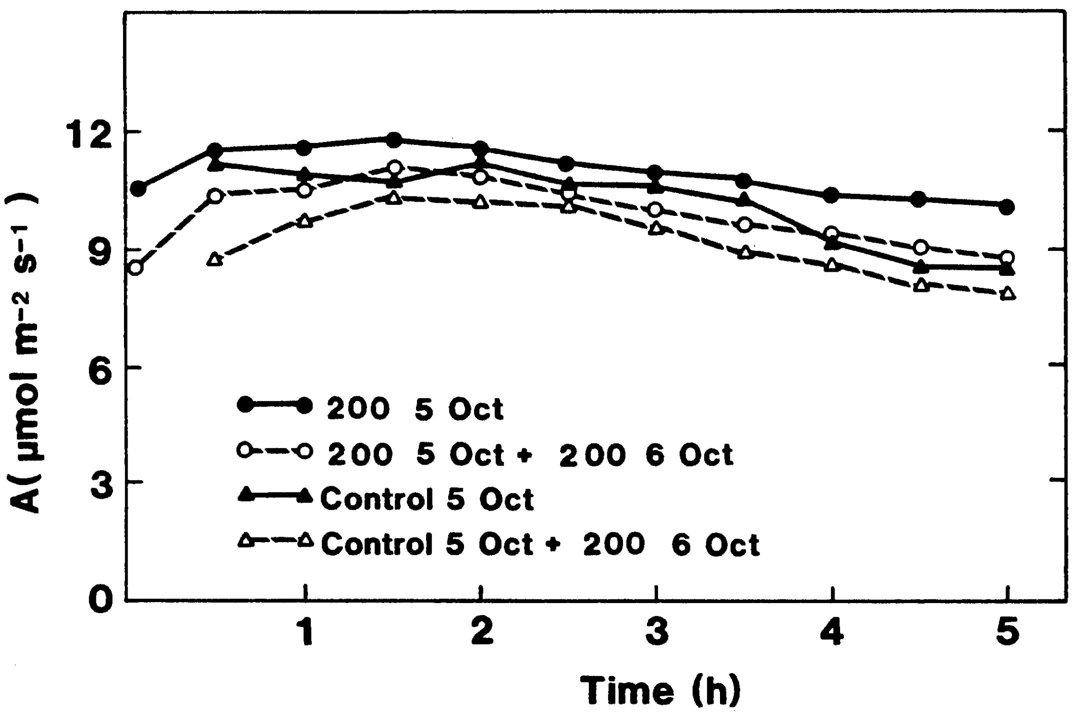

Figure 3. The response of grapevine leaves to 200 ppb O_3 on two consecutive days, five hours each day. On October 5, two leaves were exposed to 200 ppb O_3 (●——●) and another leaf was measured using charcoal filtered air (▲——▲). The following day the same two leaves mentioned previously again were exposed to 200 ppb O_3 (○----○) while the control leaf on the previous day also was exposed to 200 ppb O_3 (△----△).

APPENDIX 1

STATE: CALIFORNIA (05) AQDHS-II AIR QUALITY DATA REPORT DISPLAY (9399 PAGE 1

ADCR: 031 AGENCY(I): DISTRICT AGENCY
CNTY: 1000 PROJECT(11):
AREA: 2820 PARM(44201): OZONE
SITE: 230 UNITS(08): PARTS PER BILLION
YEAR: 1987 MONTH(05): MAY
LOCALE: 9240 SO. RIVERBEND

COLLECT METH: CONTINUOUS
ANALYSIS METH: U. V. ABSORPTION
SAMPLING INTR: 01 HOURS
SAROAD KEY: 05/2820/230/1/11
MINIMUM DETEC: 0
EARLIER

SLAMS/NAMS(2): SLAMS
RPT AGNCY/SMSA: 2840
UTM ZONE: 11
UTM EASTING: 275900
TIME ZONE(04): PACIFIC

PRIMARY SECONDARY

STATE STANDARD

IN Parts per Billion

HOURS

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MEAN
01	29		23	20	15	20	23	31	38	45	50	52	55	56	59	60	59	57	60	57	52	45	39	35	43
02	32		30	27	25	14	21	30	34	40	47	51	57	60	64	62	60	58	55	49	39	31	29	24	41
03	15		10	8	7	7	17	23	27	36	46	54	61	62	62	67	69	70	62	34	20	16	21	26	36
04	8		13	14	8	8	14	34	42	58	76	78	79	77	77	79	86	108	64	34	33	35	35	30	47
05	28		21	11	13	19	20	31	43	61	66	77	82	91	97	124	117	87	58	41	39	32	20	20	52
06	16		32	15	8	10	20	39	57	71	84	98	103	94	101	106	106	83	67	53	62	61	51	39	60
07	31		28	34	23	21	18	25	40	51	62	74	76	69	62	54	49	37	39	42	40	41	38	32	43
08	26		23	24	13	12	22	39	50	56	60	63	64	69	73	59	38	44	52	55	51	43	34	24	43
09	24		14	12	7	4	8	27	43	58	66	78	80	84	101	93	53	53	47	39	31	26	24	25	43
10	22		10	5	4	6	16	36	46	53	61	81	84	79	79	80	78	75	60	42	34	28	14	21	44
11	17		22	29	19	15	17	30	48	64	79	78	93	90	95	92	86	65	53	40	33	32	36	27	51
12	39				23	13	25	38	48	64		83	87	92	97	117	102	83	68	62	58	62	52	35	62
13	25		17	12	6	7	13	27	43	61	75	80	88	83	79	65	52	45	36	36	45	38	24	20	42
14	16		11	7	3	4	19	31	43	59	72	85	57	93	83	74	57	52	42	35	37	28	19	15	43
15	9		8	5	5	7	15	31	48	64	75	78	82	84	87	84	66						39	38	46
16	29		28	24	19	23	28	44	44	45	58	64	67	72	71	77	69	61	42	36	29	37	39	34	45
17	34		32	31	29	26	31	35	41	48	58	63	72	79	82	84	85	83	67	45	37	35	36	33	51
18																75	76	78	61	43	37	38	37	38	54
19	32	29	27	21	21	14	19	25	32	34	38	43	50	59	62	67	67	68	59	44	40	34	31	33	40
20	28	28	30	27	27	24	23	24	30	36	43	51	53	57	58	60	59	56	46	38	23	23	20	18	37
21	19	18	10	10	4	16	30	33	37	48	54	62	69	79	80	82	77	70	62	51	48	29	26	21	43
22	22	21	14	12	8	10	18	26	38	46	54	64	72	81	84	85	83	79	66	52	45	36	50	48	46
23	41	35	30	24	18	14	20	30	40	53	62	74	81	89	86	84	85	77	69	59	48	42	43	40	52
24	39	36	34	34	30	28	36	41	46	51	56	61	68	68	66	66	68	64	53	48	44	43	41	42	48
25	40	39	40	37	26	15	24	36	42	47	50	53	56	56	56	57	58	58	48	38	36	38	34	36	43
26	33	33	33	32	22	24	28	41	46	49	54	58	61	63	65	66	66	64	55	29	37	35	33	28	44
27	25	23	20	18	14	14	22	30	36	45	53	55	61	66	67	70	72	67	59	44	42	37	36	32	42
28	29	28	25	21	13	9	18	26	36	43	53	67	72	74	77	76	77	72	56	31	25	31	39	32	43
29	29	28	24	19	16	19	22	27	34	39	51	64	74	78	74	72	70	67	57	49	49	38	35	31	44
30	32	28	22	19	14	14	24	33	40	53	68	83	93	96	96	91	89	84	71	56	44	34	31	31	52
31	25	22	20	21	19	19	23	28	36	43	48	51	56	61	65	66	67	62	48	45	53	59	54	41	43
NO	30	13	29	29	30	30	30	30	30	30	29	30	30	30	30	31	31	30	30	30	30	30	31	31	704
MEAN	26	28	22	20	15	15	21	32	41	51	59	67	73	75	77	77	72	68	56	44	40	37	34	31	46
MAX	41	39	40	37	30	28	36	44	57	71	84	98	103	96	101	124	117	108	71	62	62	62	54	48	124

'MALF' - MACHINE MALFUNCTION 'WTHR' - BAD WEATHER 'VAND' - VANDALISM 'COLL' - COLLECTION ERROR
'LAB ' - LAB ERROR 'QUAL' - QUALITY ASSURANCE 'CALB' - CALIBRATION 'WAIV' - MONITORING WAIVED
'*** ' - NOT ENOUGH READINGS ' ' - NULL VALUE

AQCR: 031 AGENCY(I): DISTRICT AGENCY
CNTY: 1000 PROJECT(11):
AREA: 2820 PARM(44201): OZONE
SITE: 230 UNITS(08): PARTS PER BILLION
YEAR: 1987 MONTH(06): JUNE
LOCALE: 9240 SO. RIVERBEND PARLIER

COLLECT METH: CONTINUOUS
ANALYSIS METH: U. V. ABSORPTION
SAMPLING INTR: 01 HOURS
SAROAD KEY: 05/2820/230/I/11
MINIMUM DETEC: 0

SLAMS/NAMS(2): SLAMS
RPT AGNCY/SMSA: 2840
UTM ZONE: 11
UTM EASTING: 275900
TIME ZONE(04): PACIFIC

PRIMARY SECONDARY

STATE STANDARD

HOURS

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MEAN
01	30	23	24	20	9	10	25	37	47	58	64	67	68	79	74	75	76	83	70	50	37	19	19	7	45
02	11	24	27	24	15	12	31	57	70	81	88	91	100	114	123	161	164	133	91	52	43	41	30	33	67
03	31	25	19	24	25	18	25	57	66	79	95	112	129	138	134	126	106	78	55	26	48	41	25	21	63
04	18	20	21	19	17	14	22	36	50	57	55	65	76	84	80	85	83	76	59	60	53	44	56	55	50
05	47	40			26	25	28	34	41	47	51	60	57	74	97	116	86	75	70	56	34	29	26	19	52
06	28	33	31	34	35	34	41	55	49	54	65	74	89	88	73	72	66	59	48	46	37	21	29	24	49
07	21	12	10	8	10	12	24	39	52	64	76	82	91	99	93	84	73	65	60	48	44	38	41	32	49
08	30	30	29	26	22	25	32	38	49	63	78	91	97	105	106	90	81	76	77	58	46	38	51	44	58
09	37	32	28	24	15	15	23	37	47	66	74	70	88	101	95	81	78	62	48	38	31	22	19	24	48
10	23	24	21	15	8	5	19	29	40	56	74	83	87	102	129	108	95	71	59	50	40	40	45	31	52
11	23	21	18	13	7	17	26	34	48	62	72	87	97	102	100	106	86	72	57	39	17	29	33	36	50
12	29	30	24	18	14	10	21	34	50	66	84	96	110	111	108	102	90	78	65	52	34	47	45	40	57
13	28	16	21	25	26	31	34	43	57	70	85	99	99	100	97	101	105	104	83	72	65	59	55	45	63
14	34	29	27	15	15	16	19	27	34	48	59	72	76	75	74	71	65	60	48	31	29	29	30	27	42
5	24	25	24	23	16	11	17	25	31	36	43	47	51	55	55	54	56	56	47	31	20	21	25	40	35
16	30	24	18	10	5	5	14	23	34	44	52	64	73	71	78	82	79	75	64	46	45	42	35	29	43
17	30	29	26	22	15	14	22	29	38	47	62	73	80	84	81	78	81	75	61	59	46	35	30	28	48
18	27	25	22	20	14	15	20	25	34	46	60	74	78	80	82	81	83	82	66	45	35	27	26	20	45
19	20	16	25	21	11	11	27	42	58	72	76	94	88	86	83	77	89	87	80	51	42	44	42	34	53
20	33	28			14	17	24	31	42	58	66	73	73	77	77	81	67	58	48	39	33	39	37	26	47
21	20	17	14	14	14	13	16	20	26	34	37	37	39	42	42	44	45	48	48	49	53	52	41	36	33
22	30	24	23	16	13	11	18	25	32	40	45	56	67	73	78	83	80	88	84	60	53	20	21	14	44
23	17	18	13	10	11	14	27	41	49	64	78	90	96	114	116	101	100	91	67	48	38	23	27	23	53
24	13	10	5	6	7	12	28	52	71	80	86	84	109	146	117	110	112	101	76	61	39	26	27	18	58
25	20	13	6	7	8	13	33	46	49	64	92	103	117	120	125	124	121	107	90	85	63	40	39	49	64
26	39	35	29	20	13	13	25	40	61	78	83	104	122	136	137	150	178	150	84	63	45	58	46	43	73
27	33	31	27	17	13	14	24	33	39	50	73	94	107	112	117	125	107	97	86	74	66	56	55	47	62
28	43	42	33	24	22	21	26	36	47	56	69	81	92	88	87	88	88	80	68	58	53	36	26	30	54
29	26	30	27	22	17	10	15	27	41	52	71	80	86	85	84	87	85	83	73	59	57	43	37	35	51
30	33	30	25	21	15	9	18	30	43	59	74			84	86	86	82	76	71	60	52	46	38	35	49
NO	30	30	28	28	30	30	30	30	30	30	30	29	29	30	30	30	30	30	30	30	30	30	30	30	714
MEAN	28	25	22	19	15	15	24	36	47	58	70	79	88	94	94	94	90	82	67	52	43	37	35	32	52
MAX	47	42	33	34	35	34	41	57	71	81	95	112	129	146	137	161	178	150	91	85	66	59	56	55	178

'MALF' - MACHINE MALFUNCTION 'WTHR' - BAD WEATHER 'VAND' - VANDALISM 'COLL' - COLLECTION ERROR
'LAB ' - LAB ERROR 'QUAL' - QUALITY ASSURANCE 'CALB' - CALIBRATION 'WAIV' - MONITORING WAIVED
'*** ' - NOT ENOUGH READINGS ' ' - NUL VALUE

AQCR: 031 AGENCY(I): DISTRICT AGENCY
CNTY: 1000 PROJECT(11):
AREA: 2820 PARM(44201): OZONE
SITE: 230 UNITS(08): PARTS PER BILLION
YEAR: 1987 MONTH(07): JULY
LOCALE: 9240 SO. RIVERBEND

COLLECT METH: CONTINUOUS
ANALYSIS METH: U. V. ABSORPTION
SAMPLING INTR: 01 HOURS
SAROAD KEY: 05/2820/230/I/11
MINIMUM DETEC: 0
PARLIER

SLAMS/NAMS(2): SLAMS
RPT AGNCY/SMSA: 2840
UTM ZONE: 11
UTM EASTING: 275900
TIME ZONE(04): PACIFIC

PRIMARY SECONDARY

STATE STANDARD

HOURS

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MEAN
01	25	25	20	15	9	9	20	29	34	45	59	69	70	71	74	78	82	76	60	36	35	39	38	41	44
02	42	30	21	15	9	8	18	26	41	55	61	64	73	80	83	80	79	75	59	30	23	41	38	39	45
03	29	22	18	16	13	13	18	26	37	49	61	73	84	81	77	87	75	68	58	51	50	44	32	25	46
04	20	19	16	16	13	12	19	25	34	44	52	59	64	69	65	64	66	66	55	35	29	25	19	20	38
05	18	17			8	9	14	25	39	51	55	73	71	63	59	60	57	49	40	26	30	38	32	22	39
06	22	18	17	12	7	8	16	27	41	56					74	78	75	67	61	40	24	17	5	10	34
07	12	15	22	19	10	8	18	31	50	66	92			96	91	83	83	63	63	52	45	39	29	19	46
08	13	10	8	8	6	7	13	20	30	39	49	54	56	53	54	57	57	56	51	41	24	9	8	19	31
09	16	10	13	11	8	10	15	28	42	61	73	83	81	77	82	85	84	78	65	49	36	30	35	30	46
10	32		30	21	13	8	14	31	47	61	71	79	90	96	99	99	99	90	73	48	41	43	39	33	55
11	26		15	12	10	8	17	29	37	45	51	59	71	73	72	76	77	79	70	51	33	18	13	11	41
12	11		7	6	4	8	15	25	39	55	73	83	86	81	76	75	72	70	65	51	39	30	42	31	45
13	25		18	15	12	8	17	29	44	57	81	85	87	96	95	91	92	82	64	45	34	32	19	15	50
14	17		5	5	7	6	18	44	69	86	98	110	119	121	107	122	113	84	66	45	28	20	9	17	57
15	23				4	5	14	37	62	85	102	113	122	109	100	101	96	66	52	37	24	12	32	43	59
16	39		26	19	9	7	17	35	55	75	94	108	111	104	91	82	65	57	47	47	48	48	42	35	55
17	27		22	18	8	10	20	24	29	33	36	41	43	43	42	41	41	38	36	31	26	22	21	16	29
18	11		7	3	2	2	7	16	22	28	37	44	51	51	53	54	55	54	40	25	3	9	16	18	26
19	22		11	10	6	3	9	19	31	41	43	51	59	62	62	61	62	64	63	43	32	30	26	25	36
20	19		13	10	6	2	7	13	19	24	29	35	52	67	71	64	61	62	53	41	33	29	29	28	33
21	22		13	10	5	4	7	15	21	26				40	41	40	40	41	31	20	11	9	12	11	21
22	7		8	4	0	0	8	16	25	32	42	54	58	60	62	60	58	50	44	32	22	12	9	18	30
23	16		11	11	5	4	13	29	43	55	62	78	82	87	83	79	76	66	57	41	26	29	45	38	45
24	26		14	4	0	1	12	24	37	44	54	68	78	102	106	90	82	75	67	48	49	46	48	32	48
25	22		13	7	5	5	13	22	35	50	66	80	90	86	86	79	71	64	51	36	35	38	30	27	44
26	13		11	11	8	9	15	26	38	48	60	72	82	95	98	96	86	73	62	43	40	37	35	24	47
27	15		9	6	1	0	8	17	25	17	53	61	84	90	106	108	102	89	65	54	38	31	34	28	45
28	20		15	13	7	4	9	18	26	37	49	54	72	84	82	92	96	89	73	45	37	36	40	27	45
29	22		17	14	9	6	11	18	26	38	54	70	84	88	92	64	72	67	58	53	44	38	29	27	44
30	22				7	5	9	18	26	35	41	52	71	95	106	111	97	71	56	38	26	36	25	26	46
31	22		12	11	10	4	18	28	39	52	51	75	93	97	110	120	115	95	60	40	26	7	19	14	49
NO	31	9	28	28	31	31	31	31	31	31	29	28	28	30	31	31	31	31	31	31	31	31	31	31	707
MEAN	21	18	15	12	7	6	14	25	37	48	60	70	78	81	81	81	77	69	57	41	32	29	27	25	43
MAX	42	30	30	21	13	13	20	44	69	86	102	113	122	121	110	122	115	95	73	54	50	48	48	43	122

'MALF' - MACHINE MALFUNCTION 'WTHR' - BAD WEATHER 'VAND' - VANDALISM 'COLL' - COLLECTION ERROR
'LAB ' - LAB ERROR 'QUAL' - QUALITY ASSURANCE 'CALB' - CALIBRATION 'WAIV' - MONITORING WAIVED
'*** ' - NOT ENOUGH READINGS ' ' - NUL VALUE

STATE: CALIFORNIA (05) AQDHS-II AIR QUALITY DATA REPORT DISPLAY (9999 PAGE 4

AGCR: 031 AGENCY(I): DISTRICT AGENCY
CNTY: 1000 PROJECT(11):
AREA: 2820 PARM(44201): OZONE
SITE: 230 UNITS(08): PARTS PER MILLION
YEAR: 1987 MONTH(08): AUGUST
LOCALE: 9240 SO. RIVERBEND

COLLECT METH: CONTINUOUS
ANALYSIS METH: U. V. ABSORPTION
SAMPLING INTR: 01 HOURS
SAROAD KEY: 05/2820/230/I/11
MINIMUM DETEC: 0

SLAMS/NAMS(2): SLAMS
RPT AGNCY/SMSA: 2840
UTM ZONE: 11
UTM EASTING: 2/5900
TIME ZONE(04): PACIFIC

PARLIER

PRIMARY SECONDARY

STATE STANDARD

HOURS

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MEAN
01	6		5	8	16	22	31	40	63	76	87	91	97	110	112	113	100	94	71	55	35	26	33	32	58
02	15		13	7	5	8	19	44	63	78	103	117	109	103	94	87	88	83	63	49	38	29	24	33	55
03	27		17	17	14	8	12	24	20	20					108	131	121	91	70	63	58	43	33	35	48
04	30		20	19	11	5	11	27	46	60	68	82	102	148	134	122	99	64	45	33	29	34	34	28	54
05	14		25	22	11	9	23	46	61	68	86	110	131	174	109	80	73	64	46	29	24	20	20	19	55
06	10		25	18	11	6	12	29	47	62	69	86	96	98	95	84	78	64	52	26	17	16	16	17	45
07	15		11	20	19	17	18	30	46	66	79	99	100	95	83	76	78	76	62	39	31	24	19	14	49
08	14		15	10	9	7	13	25	37	53	77	100	95	91	90	90	94	92	66	54	43	36	28	31	51
09	25		13	10	8	10	16	27	47	66	91	91	94	87	89	84	81	71	57	34	29	19	18	46	48
10	30		18	18	9	6	15	25	38	54	70	80	94	106	99	96	90	81	58	41	33	25	24	42	50
11	38		24	17	6	5	9	18	30		54	64	72	68	64	69	71	68	55	42	34	26	40	27	41
12	22		20	9	7	3	7	21	41	51	70	76	64	57	50	59	73	74	60	41	39	36	25	28	41
13	24		24	18	12	4	11	28	40	55	62	83	82	76	69	70	71	70	55	41	27	31	28	21	44
14	15				6	2	8	17	23	31	40	49	60	60	57	55	53	52	39	32	29	25	20	18	33
15	16		12	8	4	3	8	17	26	35	44	49	55	59	63	66	64	62	51	32	15	8	12	20	32
16	6		2	2	2	2	9	26	43	58	73	85	97	108	102	104	104	94	74	48	30	20	15	14	49
17	10		3	3	4	7	14	30	59	76	76	90	96	105	121	117	104	97	71	40	39	21	20	11	53
18	17		14	10	2	3	7	16	32	48	52	72	84	90	93	94	96	91	76	60	45	40	35	33	49
19	31		25	20	14	10	9	24	38	48	59	67	79	81	88	103	108	80	62	49	45	48	37	33	50
20	30		19	14	10	6	12	19	25	34	41	49	65	69	86	85	88	83	63	45	33	20	21	25	41
21	26		16	13	6	2	5	17	28	42	59	73	81	86	89	84	81	70	43	36	15	5	5	14	39
22	19		8	5	3	4	9	24	37	49	60	72	89	95	93	92	92	82	63	42	34	33	27	27	46
23	20		17	12	9	6	10	21	30	37	47	57	70	80	92	97	90	79	66	45	38	29	22	20	43
24	19		18	14	6	2	5	15	39	57	54	74	87	82	86	92	97	86	66	30	23	20	11	7	43
25	4		3	9	13	11	12	22	43	62	77			95	96	105	110	96	69	50	30	26	16	15	46
26	12		7	5	5	6	9	30	60	75	86	89	107	103	102	111	117	98	73	47	43	30	20	23	55
27	18		12	10	9	7	7	19	42	64	76	94	101	100	101	106	110	104	60	37	30	28	33	28	52
28	32		13	18	10	7	11	30	51	70	79	100	118	123	123	117	105	76	56	49	43	49	50	39	60
29	23				13	25	19	32	47	71	90	99	98	109	125	125	117	94	72	41	55	44	29	25	64
30	39		37	40	39	35	34	46	60	72	86	100	99	95	94	97	97	88	60	32	47	48	44	39	62
31	50		40	30	22	12	13	29	50	69	83	96	119	129	142	120	96	74	72	60	59	49	43	37	65
NO	31		29	29	31	31	31	31	31	30	30	29	29	30	31	31	31	31	31	31	31	31	31	31	702
MEAN	21		16	14	10	8	13	26	42	57	70	83	91	96	95	95	92	81	61	43	35	29	26	26	49
MAX	50		40	40	39	35	34	46	63	78	103	117	131	174	142	131	121	104	76	63	59	49	50	46	174

'MALF' - MACHINE MALFUNCTION 'WTHR' - BAD WEATHER 'VAND' - VANDALISM 'COLL' - COLLECTION ERROR
'LAB ' - LAB ERROR 'QUAL' - QUALITY ASSURANCE 'CALB' - CALIBRATION 'WAIV' - MONITORING WAIVED
'*** ' - NOT ENOUGH READINGS ' ' - NUL VALUE

STATE: CALIFORNIA (05) AQDHS-II AIR QUALITY DATA REPORT DISPLAY (9999 PAGE 5

ASCR: 031 AGENCY(I): DISTRICT AGENCY
CNTY: 1000 PROJECT(11):
AREA: 2820 PARM(44201): OZONE
SITE: 230 UNITS(08): PARTS PER MILLION
YEAR: 1987 MONTH(09): SEPTEMBER
LOCALE: 9240 SO. RIVERBEND

COLLECT METH: CONTINUOUS
ANALYSIS METH: U. V. ABSORPTION
SAMPLING INTR: 01 HOURS
SAROAD KEY: 05/2820/230/I/11
MINIMUM DETEC: 0

SLAMS/NAMS(2): SLAMS
RPT AGNCY/SMSA: 2840
UTM ZONE: 11
UTM EASTING: 275900
TIME ZONE(04): PACIFIC

PARLIER

PRIMARY SECONDARY

STATE STANDARD

HOURS

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MEAN
01	31		18	10	5	6	11	25	53	72	92	107	126	132	134	128	106	87	78	52	51	45	46	27	63
02	23		16	17	16	14	15	24	38	58	72	89	100	116	136	127	94	66	57	43	46	47	37	17	55
03	15		12	14	14	8	7	15	27	40	57	73	80	80	89	103	97	70	43	24	15	17	6	3	40
04	3		3	3	4	4	6	13	24	35	50	75	89	93	103	97	93	77	48	21	16	17	18	21	40
05	21		13	8	7	4	6	14	26	36	57	72	77	80	80	73	64	56	37	21	25	15	15	19	36
06	14		15	18	11	8	12	18	24	30	36	53	69	81	81	82	81	74	49	31	29	17	13	6	37
07	17		23	18	11	6	8	18	35	52	66	76	82	85	83	82	79	66	35	23	19	17	20	17	41
08	12		7	3	3	4	6	14	38	51	66	78	89	93	93	100	113	95	70	37	30	23	7	19	46
09	38		29	44	33	12	9	36	65	75	86	93	104	113	116	115	109	100	75	27	38	58	44	35	63
10	30		21	17	7	4	9	19	30	44	57	66	81	94	104	95	73	47	27	14	15	15	26	25	40
11	22		11	7	5	3	5	13	27		72	66	65	70	81	75	58	40	23	16	16	11	12	9	32
12	10		8	6	6	3	6	12	21	31	42	56	63	68	69	68	60	51	40	33	23	22	16	27	32
13	26				15	12	9	18	28	39	50	59	62	67	69	69	68	61	42	29	18	16	16	13	37
14	12		14	10	7	4	6	16	31	45	58	68	78	81	82	80	78	64	41	30	21	10	13	15	38
15	24		20	15	8	5	8	21	41	56	62	75	85	98	106	106	99	71	44	28	14	10	11	12	44
16	16		7	7	5	7	7	17	36	70	82	95	103	110	114	114	105	79	41	13	15	17	14	15	47
17	14		9	6	8	6	9	25	42	43	57	77	84	91	109	113	97	74	42	26	13	14	13	9	43
18	10		8	9	7	6	7	13	34	61	81	91	99	105	106	131	108	75	57	42	22	25	12	19	49
19	9		8	7	9	18	20	29	46	62	77	88	95	104	105	113	129	82	59	43	34	23	30	15	52
20	11		5	8	8	17	14	33	55	67	83	91	95	97	96	100	98	94	45	29	36	27	14	13	49
21	10		19	28	28	10	9	24	54	69	90	102	109	115	123	130	121	89	55	33	13	22	29	7	56
22	21		38	38	24	15	8	29	50	77	84	108	112	115	113	109	104	71	49	36	33	34	34	26	58
23	21	12	16	13	13	9	5	19	48	53	56	53	61	64	64	61	65	34	26	16	20	12	10	12	32
24	13		17	13	7	7	7	10	24	40	58	82	94	102	109	128	89	57	35	24	22	23	19	15	43
25	13		11	4	4	3	5	10	22	35	51	68	74	68	68	68	64	45	31	21	17	11	17	17	32
26	14		12	15	10	9	10	22	39	54	78	87	91	96	99	101	97	77	54	40	18	24	13	13	47
27	13		17	26	26	17	18	32	52	62	77	98	106	107	117	136	130	107	75	49	34	30	18	25	60
28	15				9	7	8	23	52	73	83	93	109	121	130	161	139	79	49	31	32	35	31	25	62
29	20		8	22	19	24	9	14	45	76	86	91	106	115	123	132	112	76	33	27	22	16	15	12	52
30	16		19	31	21	25	35	38	58	72	84	101	119	122	118	120	112	81	68	24	37	18	21	23	59
NO	30	1	28	28	30	30	30	30	30	29	30	30	30	30	30	30	30	30	30	30	30	30	30	30	686
MEAN	17	12	14	15	12	9	10	20	39	54	68	81	90	96	101	104	95	72	48	29	25	22	20	17	46
MAX	38	12	38	44	33	25	35	38	65	77	92	108	126	132	136	161	139	107	78	52	51	58	46	35	161

'MALF' - MACHINE MALFUNCTION 'WTHR' - BAD WEATHER 'VAND' - VANDALISM 'COLL' - COLLECTION ERROR
'LAB ' - LAB ERROR 'QUAL' - QUALITY ASSURANCE 'CALB' - CALIBRATION 'WAIV' - MONITORING WAIVED.
'*** ' - NOT ENOUGH READINGS ' ' - NUL VALUE

STATE: CALIFORNIA (05)   AQDHS-II AIR QUALITY DATA REPORT   DISPLAY (9999 PAGE 6

AQCR: 031 AGENCY(I): DISTRICT AGENCY   COLLECT METH: CONTINUOUS   SLAMS/NAMS(2): SLAMS
CNTY: 1000 PROJECT(11):   ANALYSIS METH: U. V. ABSORPTION   RPT AGNCY/SMSA: 2840
AREA: 2620 PARM(44201): OZONE   SAMPLING INTR: 01 HOURS   UTM ZONE: 11
SITE: 230 UNITS(08): PARTS PER MILLION   SAROAD KEY: 05/2820/230/I/11   UTM EASTING: 275900
YEAR: 1987 MONTH(10): OCTOBER   MINIMUM DETEC: 0   TIME ZONE(04): PACIFIC
LOCALE: 9240 SO. RIVERBEND   PARLIER

PRIMARY   SECONDARY

STATE STANDARD

HOURS

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MEAN
01	17		20	28	36	34	37	42	57	73	82	99	118	124	125	131	121	81	59	56	39	34	28	41	64
02	38		29	15	19	8	10	24	45	71	91	109	115	134	146	140	117	82	46	27	41	31	22	10	60
03	10		17	20	23	19	16	32	50	70	85	99	115	130	132	165	123	85	54	52	44	39	42	33	63
04	25		21	34	44	45	38	38	53	67	79	92	100	106	110	111	104	93	65	34	22	36	12	17	59
05	26		37	41	29	45	41	32	47	62	73	85	95	102	100	99	89	53	23	23	31	36	31	17	53
06	27		22	37	26	13	9	16	50	67	82	104	110	111	114	114	95	57	17	43	29	37	39	30	54
07	25		24	16	14	9	8	13	26	37	55	69	87	86	102	72	58	37	32	32	36	39	29	31	41
08	28		15	13	10	7	9	12	26	46	65	73	78	89	93	90	85	58	15	10	8	21	16	16	38
09	12		13	17	15	11	9	12	33	58	70	80	95	92	90	88	80	62	38	33	32	22	25	26	44
10	20		10	8	5	4	4	10	21	35	46	58	68	81	86	89	79	57	48	14	23	20	17	12	35
11	17		10	8	9	9	9	14	27	57	77	90	105	121	107	104	95	73	58	42	44	44	43	42	52
12	36		13	10	7	8	9	14	27	41	59	75	76	75	71	66	57	37	36	40	32	21	18	20	37
13	17				7	7	6	11	22	35	52	58	64	75	78	82	76	37	40	13	7	25	7	8	35
14	6		6	6	6	6	6	14	39	61	69	83	87	95	108	123	103	75	39	20	18	19	27	10	45
15	9		26	20	13	8	8	16	46	64	74	91	103	106	110	109	102	59	21	33	39	19	31	16	49
16	15		18	22	16	11	7	15	42	66	77	91	101	99	103	131	106	45	9	16	16	22	18	20	46
17	23		13	7	6	6	9	19	38	58	76	84	92	100	102	105	91	53	68	57	40	31	18	22	49
18	19		20	31	35	34	27	32	44	61	81	86	96	100	100	104	101	78	57	58	51	22	12	19	55
19	10		27	34	33	27	12	22	42	59	72	79	86	93	100	102	97	55	17	12	19	21	23	20	46
20	14		8	11	18	19	8	11	34	47	58	68	75	85	90	88	63	39	31	30	32	41	32	26	40
21	19		15	13	9	9	8	10	22	41	62	67	71	78	84	85	66	46	12	17	14	13	33	37	36
22	26		38	53	45	28	32	25	27	33	43	39	46	48	53	63	49	38	27	16	16	29	28	21	36
23	20		12	13	13	13	11	14	19	29	41	45	44	43	45	50	46	25	11	11	12	7	4	3	23
24	4		3	3	4	4	5	9	14	19	28	39	48	50	49	40	33	20	6	6	5	5	6	6	18
25	6		5	5	5	4	4	7	18	30	45	52	55	59	61	77	58	29	12	10	6	7	8	8	25
26	7		6	6	6	5	6	13	24	39	54	63	61	64	80	72	41	32	20	8	6	6	6	7	27
27	8		6	6	6	7	8	14	28	40	37	40	39	50	34	26	30	29	30	24	19	16	15	16	23
28	28				26	20	15	13	22	26	26	29	38	43	43	42	38	27	20	24	30	27	22	20	28
29	26		33	33	28	16	15	16	21	24	28	33	36	39	41	38	30	17	12	10	8	7	7	6	23
30	5		4	4	4	4	5	8	11	19	26	37	43	44	45	39	35	24	10	5	5	7	7	6	17
31	6		6	7	8	7	6	7	15	16	16	17	18	19	24	20	15	12	14	12	11	9	9	9	12
NO	31		29	29	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	709
MEAN	18		16	18	17	14	13	17	32	47	59	69	76	82	85	86	74	49	31	25	24	23	20	19	40
MAX	38		38	53	45	45	41	42	57	73	91	109	118	134	146	165	123	93	68	58	51	44	43	42	165

'MALF' - MACHINE MALFUNCTION   'WTHR' - BAD WEATHER   'VAND' - VANDALISM   'COLL' - COLLECTION ERROR
'LAB ' - LAB ERROR   'QUAL' - QUALITY ASSURANCE   'CALB' - CALIBRATION   'WAIV' - MONITORING WAIVED
'*** ' - NOT ENOUGH READINGS   '   ' - NUL VALUE

APPENDIX 2

Table A2-2. Analysis of variance of the effect of ozone concentrations and grape cultivar on leaf net CO_2 assimilation. Data were analyzed as a two-way factorial.

Source	df	Sum of Square	F
Blocks	11	108	4.6
Cultivar	5	31	2.9*
Treatment	1	18	8.3*
Interaction	5	59	5.5**
Error	24	51	

*,** = $P < 0.05$ and 0.01, respectively.

Table A2-1. Analysis of variance for the effects of ambient pollutants on leaf photosynthesis measured on four different dates.

Measurement Date	Source	dF	Sum of Squares	F
May 5	Treatment	2	0.05	5.1
	Error	15	0.08	
June 25	Treatment	2	50.5	19.5**
	Error	6	7.8	
August 7	Treatment	2	24.2	5.3*
	Error	15	34.2	
September 21	Treatment	2	50.9	14.3***
	Error	15	27.7	

*, **, and *** = $P < 0.05$, 0.01 and 0.001, respectively.