THE EFFECTS OF OZONE AND SO_2 ON ALFALFA YIELDS AND HAY QUALITY

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SUMMARY

The Effects of Ozone and Sulfur Dioxide on
Alfalfa Yields and Hay Quality

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Alfalfa (Medicago sativa L.) is an extremely important crop in California, ranking only below number 1 cotton and number 2 grapes in dollar value. Although alfalfa has long been recognized as especially sensitive to damage by air pollution, it is only in recent years that attempts have been made to quantify the relationship between exposure and economic damage. Most previous studies involved container-grown plants and involved only a few cuttings. An air pollution effects experiment more nearly approximating "field conditions" was initiated at the University of California San Joaquin Valley Research and Extension Center near Reedley in the spring of 1979. Two varieties of alfalfa, Moapa and WL-512 were grown in prepared soil beds surrounded by 12 foot square, open top, blower-ventilated, plastic covered chambers. Seventeen hay cuttings were harvested over a period of three seasons from alfalfa plots exposed to varying amounts of ozone (3 levels) with and without SO_2. Both the quantity and quality of each cutting was measured and correlated with pollutant doses calculated by totaling the mean hourly averages greater than 10, 5, or 15 PPHM.

Yields

The two alfalfa varieties responded quite differently to ozone. Ambient ozone concentrations (season dose of approximately 75-100 PPHM-hrs

over threshold of 10) reduced Moapa yields approximately 8 to 13% but had no measureable effect on variety WL-512. Exposure to a SO_2 concentration of 10 PPHM for six hours four times per week reduced yields by both varieties approximately 9%. Moapa yields were reduced approximately 17% by a combination of ambient ozone levels and the SO_2 treatment. Increasing the ambient ozone concentration by 50% decreased yields by Moapa an additional 19% for a total of 27% compared with the pollution-free, filtered air treatment. WL-512 yields were depressed approximately 10% by the high ozone treatment, indicating that even this "ozone tolerant" variety would suffer significant economic damage if San Joaquin Valley air quality were to deteriorate to the levels used in this experiment. There was no indication that ozone and SO_2 in the concentrations used are synergistic, but their effects are additive. Stand counts made in the spring and fall of 1980 and 1981 indicated increased Moapa mortality with increasing ozone pollution dose, and increased mortality of both varieties with exposure to SO_2.

Quality

Alfalfa hay quality, as indicated by protein, fiber and total digestible nutrient (TDN) contents, was not significantly effected by the treatments used in this experiment. There was some indication that exposure to high ozone or SO_2 can reduce leafiness, but the data were not always consistent in this respect.

Conclusions

Yields of the widely planted alfalfa variety Moapa are being reduced significantly by ambient levels of ozone. Should present air quality deteriorate sufficently to increase ozone levels by 50% the extent of damage would approximately double. The presence of SO_2 in concentrations approaching 0.1 PPM (10 PPHM) would also significantly reduce Moapa and WL-512 yields. WL-512 is apparently resistant to present ambient levels of ozone but would be damaged by a 50% increase in mean daily ozone concentration. Increasing pollution levels, both ozone and SO_2, could be expected to increase stand mortality thereby reducing the expected life of alfalfa plantings.

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DISCLAIMER STATEMENT

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THE EFFECTS OF OZONE AND SO_2 ON ALFALFA YIELDS AND HAY QUALITY

Robert F. Brewer and Rulon Ashcroft

Alfalfa (Medicago sativa L.) is an extremely important crop in California, especially in the great Central Valley, ranking just below cotton and grapes in dollar value. Although alfalfa has long been recognized as being especially sensitive to air pollution, yield data relating crop size and quality to air pollution exposure under field conditions has been lacking. Observations and growth chamber experiments carried out by Thomas and Hill (1933, 1935) in the vicinity of a large metal smelter near Salt Lake City in the early 1930's demonstrated the sensitivity of alfalfa to SO_2 air pollution and established criteria for estimating the extent of damage so that farmers could be reimbursed for observed damage. The injurious effects of oxidants, particularly ozone on alfalfa, have been reported by Ledbetter (1959), Brennan (1969), Hill (1961), Howell (1971), Oshima (1976), and Thompson (1976). Howell (1971) tested 14 different varieties for ozone resistance and demonstrated that this characteristic could be enhanced by selection and breeding. Thompson (1976) exposed "susceptible" and "tolerant" alfalfa varieties grown in pots to filtered and non-filtered air near Riverside, California and determined effects on forage yields, stand counts, chemical content, and feeding quality. Oshima (1976) using Moapa 69 variety alfalfa growing in pots and located at nine different southern California locations having varying seasonal O_3 doses, established yield and leaf loss regression functions which could be used to estimate reductions in yield or leafiness of Moapa alfalfa if one knew the seasonal ozone dose (pphm hours greater than 10 pphm from April 1 through October 31). Oshima's data would predict 2.5 to 5 percent yield and .8 to 1.5 percent leaf losses for the Fresno area. Because Oshima's yield-exposure functions were based on only five cuttings from potted plants grown for a single season (alfalfa plantings root very deeply and typically persist three to five seasons with seven or eight cuttings per season) a three year experiment was initiated in 1979 to evaluate alfalfa response to oxidants and/or SO_2 over a longer period under conditions more nearly approximating those found in the field. Although Moapa 69, the variety used in Oshima's tests, is still the most popular single variety planted in Central California, it is an old variety and as such will probably be eventually replaced by one or more of the promising newer varieties such as WL-512.

Test Plots and Chambers

The two alfalfa varieties, Moapa 69 and WL-512 were seeded directly into the ground beds of open top fumigation chambers in May 1979. These chambers, previously used in similar experiments with sugarbeets[1/] and cotton[2/] were igloo-shaped with 3.66m (12 ft) square bases and a 3.05m (10 ft) open top 2.74m (9 ft) above the soil surface. Figure 1 is a schematic overhead projection showing the square base and circular open top. The enclosed square plot was divided into six equal subplots by two of the partially submerged air ducts and a redwood partition (see Figure 2). In one rep. subplots A, C, and E were planted to Moapa 69 and B, D, and F

1/ Final Report - CARB Agreement A6-161-30

2/ Final Report - CARB Agreement A7-119-30

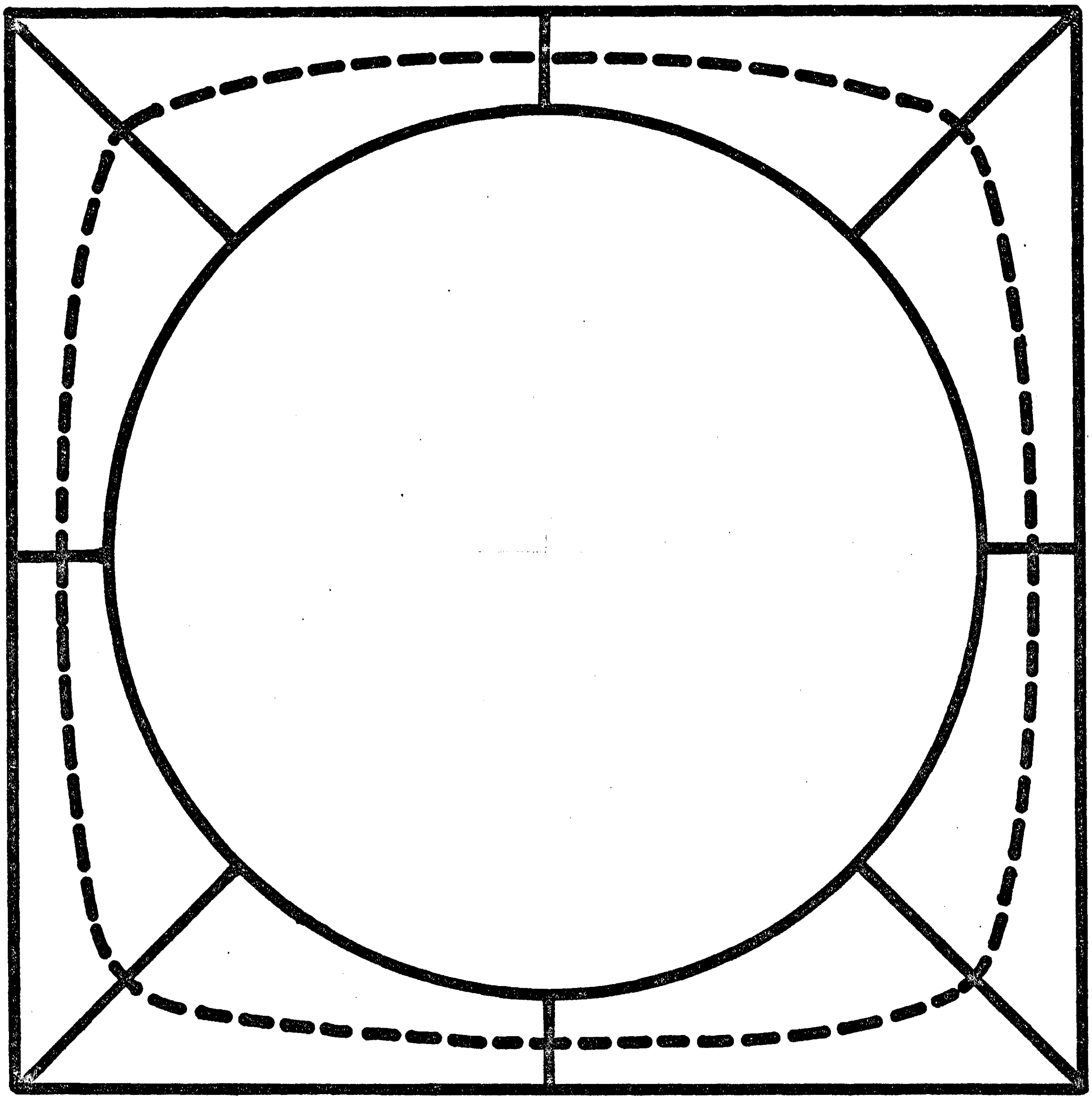
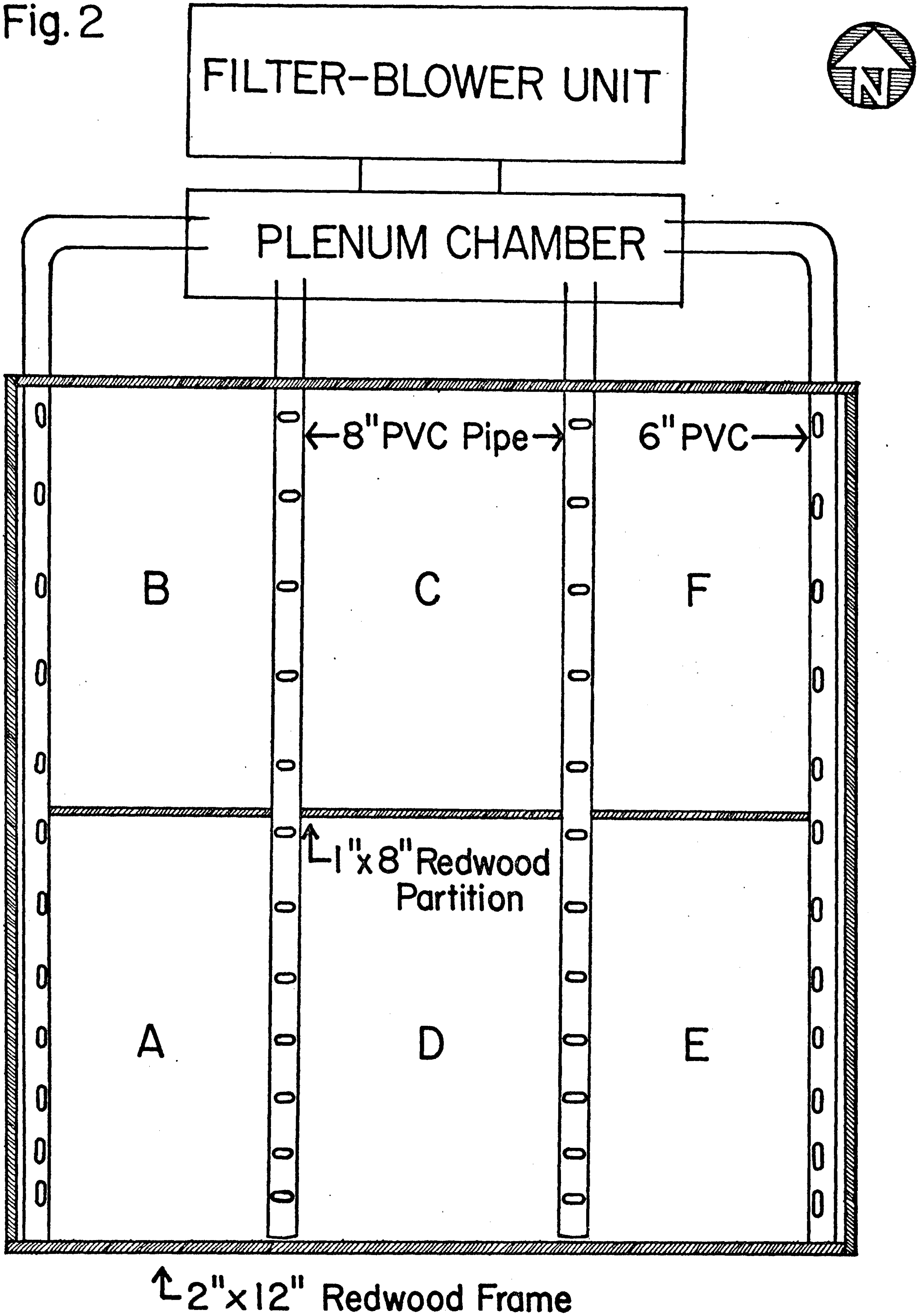


FIGURE 1.
SCHEMATIC OVERHEAD PROJECTION OF TEST PLOT AND GROWTH CHAMBER. PLOT IS 3.66M SQUARE, OPEN TOP IS 3.05M IN DIAMETER.

Fig. 2


FILTER-BLOWER UNIT
PLENUM CHAMBER
N
8"PVC Pipe
6"PVC
B
C
F
A
D
E
1"x8" Redwood Partition
2"x12" Redwood Frame

were planted to WL-512. In the second rep. the planting pattern was reversed to avoid an orientation bias.

All of the chambers were equipped with motor driven blowers which supplied approximately 2200 CFM of air through the four ground level air ducts; more than enough to change the chamber volume twice per minute. The chambers were glazed with 8 mil clear calendered polyvinyl plastic obtained from Hartwig-Hartoglass Corporation in Woodstock, Illinois. Absorbance measurements made previously on several clear plastics indicated polyvinyl superior to the other plastics for light transmission over the 4 to 7 micron spectrum[3/].

Light transmission by the plastic was found to be excellent with measured light intensities ranging from 98 to 99 percent of outdoor readings. Air movement measured with a hot wire anemometer ranged from .31 m/s during relatively calm morning and late afternoon hours to 1.41 m/s around noon when the prevailing down-valley drift or wind is strongest.

Cultural Conditions

Cultural growing conditions as similar to "field conditions" as possible were maintained during the experiment. The plants were grown in open beds (not pots) having unlimited depth for root extension. This is especially important for alfalfa which will send roots 3 to 5 meters down into the subsoil. Since the beds were not raised or otherwise subject to unusual radiation exposure, soil temperature was essentially the same in the chambers as in outside plots. As in the field, irrigation was applied one or two times between cuttings by deep soaking. Irrometers

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3/ See A6-161-30 Final Report page 9 for absorption data.

installed in all plots at 30 cm (12") and 60 cm depths were used to monitor soil moisture tension. Water was applied when readings at both depths approached 80 CB and was continued until a lowering of tension at the lower depth signaled penetration of moisture to that point.

Aphids, the only serious insect problem, were controlled by minimum applications of Pirimore™. Fertilizer applications included a preplant application of 1.36 Kg of 15-15-15 commercial fertilizer and 2.25 Kg of gypsum ($CaSO_4$) per plot. The latter was added to remove any possibility of sulfur deficiency which could influence plant response to SO_2 as an air pollutant. Alfalfa cuttings were made as in the field at approximately 10 percent flowering and 10 to 15 cm (4 to 6 inches) of regrowth. Electric hedge clippers equipped with a 7.5 cm ground skid to regulate cutting height were used to cut the mature alfalfa. Subplots were harvested, sampled and weighed separately.

Stand counts were made twice each season by placing a standard 25.7 cm (10 1/8 inch) hoop over a randomly predetermined and marked (with plastic pegs) area in each subplot. The number of individual plants within the hoop area were counted and the density multiplied to give the number per square foot.

Leaf-stem ratios were determined by stripping the leaves off of ten plants per subplot, then weighing the two portions after drying to constant weight.

Fumigation and Instrumentation

Initially four of the seven treatments (see Table 1) involved supplying filtered air. This was accomplished by pulling air through folded activated carbon filters (three 2' x 2' x 8" filters per unit).

To this filtered air was added SO_2 or O_3 in treatments numbered 2, 3, and 4. Ozone (O_3) was produced by electrical discharge using an Orec Ozonator (Ozone Research and Equipment Corporation). Sulfur dioxide (SO_2) was metered from gas bottles using a system of precision gauges, valves and capillary tubing enclosed in a temperature controlled enclosure developed by Ron Oshima while at U.C., Riverside. Both the O_3 and SO_2 gases were transported in Teflon tubing to the blower chambers where they entered the air stream just ahead of the large blower wheel.

Teflon tubing was also used for air sampling with a separate line for each plot or chamber. A central vacuum system kept the sampling lines purged when they were not being sampled by the ozone or SO_2 analyzers. Three-way teflon valves controlled by a central clock timer switched the various analyzers among the several chambers or outside plots. Individual plots were sampled for three minutes then off for nine minutes. Three Daisibi 1003AH ozone analyzers and one TECO 43 SO_2 analyzer were used for continuous monitoring. All of the ozone monitors were regularly calibrated by California Air Resources Board personnel. The TECO SO_2 analyzer was calibrated by simultaneously comparing it over a range of 0 to .15 ppm with a recently calibrated instrument borrowed from the Air Resources Board.

Analog outputs from the analyzers were recorded on multipoint strip chart recorders and transcribed weekly. Ozone dose values for the 1979, 1980 and 1981 seasons were calculated by totaling the mean hourly averages greater than 10, 5 or .5 pphm (.1, .05 or .005 ppm) and were expressed as parts per hundred million hours (pphm-hrs) for the season. Ozone additions for treatments 3 and 4 (see Table 1), which involved adding manufactured ozone to filtered air in amounts necessary to produce ambient or 1.5 time ambient doses, were based on a running dose accumulation determined weekly. To compensate for ozone dose accumulated after working hours (a technician worked until 6:30 p.m.) and on weekends the concentrations in these treatments were sometimes increased by up to 50% over outside ambient concentrations but was not allowed to exceed 2.0 pphm nor did the 1.5 ambient level exceed 2.5 pphm.

Shielded air temperatures within the plant canopy and inside the air ducts were monitored on a continuous basis and like the ozone and SO_2 values recorded with a multipoint analog recorder. Differences in temperature between plots served as an early warning system of blower malfunction usually associated with broken or loose drive belts. Ordinarily the enclosed chamber plots averaged $1^{\circ}C$ higher temperatures both at midnight and midafternoon compared with open, non-enclosed plots. Relative humidity within the plant canopy, measured periodically with a Weather Measure solid state relative humidity probe, was very nearly the same in the ventilated, enclosed plots as in non-enclosed outside plots.

Treatments

The treatments used in these experiments involved three levels of oxidant (ozone) and two levels of SO_2. The seven treatments are listed in Table 1. Treatment number 3, which involve simulating ambient air by adding ozone to filtered air, was discontinued in 1981. Treatment number 4, which also involved adding O_3 to filtered air to provide a 1.5 ambient ozone dose, was changed to adding ozone to ambient air in 1981. Maintaining these two treatments proved very difficult without exposing the plants to excessively high concentrations of O_3 during working hours to compensate for ambient dose experienced on Sundays or after working hours,

Table 1. Treatments Utilized in Air Pollution Experiment with Alfalfa 1979-1981

Treatment	Abbreviation	Description
1	Filt.	Air filtered through activated carbon
2	Filt.+SO_2	10 pphm (.1 ppm) SO_2 added to filtered air
3*	Filt.+1AO_3	Ambient levels of ozone (O_3) added to filtered air
4**	Filt.+1.5AO_3	1.5 times ambient levels of ozone added to filtered air
5	Amb.	Ambient air (no filtration)
6	Amb.+SO_2	Ambient air plus SO_2
7	Outside	Outside plot

* This treatment was discontinued in 1981.
** This treatment was changed to ambient plus additional O_3 to give 1.5 times ambient O_3 in 1980.

Dry SO_2 gas was metered into the chambers receiving treatments 2 and 6 in sufficient quantity to produce a concentration of 10 pphm for 6 hours 4 days per week. The plots were never exposed to SO_2 for more than 6 hours in any 24 hour period. The actual ozone and SO_2 doses which the alfalfa received in the various treatments are listed in Table 2.

Results and Discussion

Four cuttings were obtained the first season (1979) and eight cuttings in 1980 and 1981. The first cutting in each year was not subjected to the various treatments and therefore was not included in the yields summarized in Tables 3 and 4.

Of the two varieties, Moapa is more sensitive to ozone - both are equally sensitive to SO_2. Filtering out ambient oxidants increase Moapa yields by an average of 8 percent but had no effect on WL-512 yields.

Table 2. Ozone and SO_2 doses in pphm-hrs to which alfalfa was exposed, 1979 - 1981

Treatment	ppm-hrs-1979				pphm-hrs-1980				pphm-hrs-1981			
	O_3>10	O_3>5	O_3>.5	SO_2>1	O_3>10	O_3>5	O_3>.5	SO_2>1	O_3>10	O_3>5	O_3>.5	SO_2>1
1. Filt.	0	4	2358	-	5	186	4126	-	0	0	2061	-
2. Filt.+SO_2	0	4	2358	3120	5	186	4126	4560	0	0	2061	6740
3. Filt.+1AO_3	327	2516	7336	-	849	4325	11319	-	(Discontinued)			
4. 1.5 Amb. O_3*	1734	5227	10453	-	3209	8189	15618	-	2816	9269	20530	-
5. Amb. O_3	78	1910	10700	-	183	3333	15690	-	99	2710	14039	-
6. Amb.+SO_2	78	1910	10700	3120	183	3333	15690	4560	99	2710	14039	6740
7. Outside	181	2581	12620	-	413	4454	17933	-	253	3877	15933	-

* Filtered air plus 1.5 times ambient ozone on 1979, 1980 manufactured ozone added to ambient air to produce 1.5 times ambient O_3 in 1981.

Table 3. Moapa alfalfa yields in Kg per plot for 1979, 1980, and 1981 based on 10% moisture content

Treatment	1979		1980		1981		17 Cutting Total	
	Yield	% Amb.	Yield	% Amb.	Yield	% Amb.	Yield	% Amb.
1. Filt.	6.70a*	115	21.66a	102	20.35a	113	48.71a	108.2
2. Filt.+SO_2	6.43a	110	19.52ab	92	18.40ab	102	44.35b	98.6
3. Filt.+1AO_3	6.07ab	104	19.58ab	97	(Discontinued)		-	-
4. Filt.+1.5AO_3**	4.92c	84	16.82b	79	14.86c	88	36.60c	81.3
5. Amb.	5.85b	100	21.20a	100	17.94b	100	44.99b	100.0
6. Amb.+SO_2	5.24bc	89	18.56ab	88	16.96bc	94	40.76d	90.8
7. Outside	6.29ab	107	22.29a	108	17.80b	99	47.30a	105.1

* Plot means not sharing same subscript letter are significantly different at 5% probability level using Duncan's Multiple Range test.

** Changed to ambient plus .5 Ambient O_3 in 1981.

Table 4. WL-512 alfalfa yields in Kg per plot for 1979, 1980 and 1981 based on 10% moisture content

Treatment	1979 Yield	1979 % Amb.	1980 Yield	1980 % Amb.	1981 Yield	1981 % Amb.	17 Cutting Total Yield	17 Cutting Total % Amb.
1. Filt.	7.14a*	101	21.04a	99	18.53a	99	46.71a	99.8
2. Filt.+SO_2	6.38ab	92	18.59b	87	18.06a	97	43.03b	91.9
3. Filt.+1AO_3	6.04b	87	20.13ab	94	(Discontinued)		-	-
4. Filt.+1.5AO_3**	6.15b	88	19.12b	90	16.90b	91	42.17b	90.1
5. Amb.	6.96a	100	21.30a	100	18.54a	100	46.80a	100.0
6. Amb.+SO_2	6.28b	90	18.66b	88	17.37b	94	42.31b	90.4
7. Outside	6.92a	99	23.42a	105	16.98b	92	47.30a	101.1

* Plot means not sharing the same subscript are significantly different at 5% probability level using Duncan Multiple Range test.

** Changed to ambient plus .5 Ambient O_3 in 1981.

Exposure to 0.1 ppm SO_2 six hours per day, four days per week reduced yields of both varieties by approximately 8 percent compared with the pollution free filtered treatment.

There is no indication that the combination of ozone and SO_2 is synergistic, but their effects are additive. This is evident from the Moapa yield data which indicate 8.2 percent yield reduction due to ambient ozone, a 9.6 percent reduction due to exposure to SO_2 alone, and a 17.4 percent reduction with a combination of SO_2 and ambient ozone. Increasing the ambient ozone concentration by 50 percent decreased Moapa yields an additional 19 percent compared with the ambient treatment or 27 percent compared with the filtered air treatment. WL-512 yields were depressed approximately 10 percent by the high ozone treatment indicating that even this "ozone tolerant" variety would be significantly damaged if ambient levels of ozone were to increase by 50 percent. If levels of SO_2 should approach 10 pphm together with increases in ambient ozone the consequences would be especially costly to the valley alfalfa grower.

Stand Counts

An important aspect of commercial alfalfa production is crop life. Any factor which significantly reduces the expected life of an alfalfa planting is of prime importance. Initially as individual plants die, their neighbors spread out to take up the available space, but eventually weeds and grasses move in as the larger alfalfa clones succumb. Intrusion by too many weeds and grasses severely reduce both yields and quality, thereby reducing net income per acre. The expected profitable life of an alfalfa planting ranges from one to five or more years depending on many factors. One of the factors is exposure to air pollutants as indicated by the stand count data in Table 5.

Table 5. Alfalfa stand counts made in the spring and fall of 1980 and 1981

	1980				1981			
	Moapa		WL-512		Moapa		WL-512	
Treatment	7/29	11/5	7/29	11/5	4/7	10/26	4/7	10/26
1. Filt.	55ab*	50ab	50 NSD	50ab	40ab	42a	39a	39 NSD
2. Filt.+SO_2	72a	69a	67	67a	39ab	39ab	36a	28
3. Filt.+1AO_3	46b	45b	57	50ab	(Discontinued)			
4. Filt.+1.5AO_3	65ab	57ab	53	49ab	35ab	27ab	26ab	26
5. Amb.	54ab	49b	53	47b	46a	35ab	40a	43
6. Amb.+SO_2	55ab	49b	58	54ab	32ab	29ab	29ab	30
7. Outside	68a	57ab	68	57ab	25b	24b	25b	27

* Means not sharing the same subscript letter are significantly different at .05 level using Duncan's (1955) Multiple Range test.

Plots receiving filtered air retained 76 percent of their Moapa plants and 78 percent of their WL-512 stand. Ambient Moapa plots retained only 65 percent and with high ozone only 54 percent of their original stand. Mortality of both varieties increased substantially when exposed to SO_2. It is interesting to note that the highest mortality occurred in the two outside plots.

Hay Quality

To a dairy farmer the quality of hay is very important because milk production is closely correlated with protein content and percentage of digestible dry matter (TDN). Stage of growth at cutting is important with protein content and digestibility dropping as much as .5 percent each day cutting is delayed past 1/10th bloom. Leafiness is also important since the foliage contains more of the protein and digestible materials than do the fibrous stems.

Oven dried samples of 17 cuttings (3 in 1979 and 7 each in 1980 and 1981) were analyzed for fiber and protein content. The 1979 samples were analyzed using standard wet chemistry methods (Bath, et al., 1978) by the University of California Agricultural Extension Service Laboratory at U.C. Davis headed by Dr. James Quick. The 1980 and 1981 samples were analyzed for protein content using a Technicon infrared autoanalyzer (InfraAlyzer 400) calibrated using samples previously analyzed by Dr. Quick's laboratory. Modified crude fiber was determined in both laboratories using standard industry procedures (Bath, et al., 1978). Table 6 summarizes the protein, modified crude fiber (MCF) and total digestible nutrient (TDN) contents found associated with the various treatments.

Results of these analyses indicated no significant differences in protein contents due to the various air pollution treatments, but MCF and therefore TDN was slightly different in several instances, but the differences were never of any practical significance.

Another criteria of quality is leafiness which is determined by stripping off the leaves and determining the ratio of leaf weights to stem weights. Table 8 contains leaf per stem ratio data for alfalfa harvested September 19, 1979, August 29, 1980 and July 27, 1981. These data indicate a trend toward reduced leafiness associated with exposure to SO_2 and the high ozone treatment but there were no significant differences associated with ambient ozone concentrations. The leaf/stem ratio data was extremely variable with very low and very high values coming from different subplots of the same variety and treatment. Had the ozone and SO_2 treatments been sufficiently high to cause foliar abscission, greater differences would have been found. Very little leaf abscission was observed in these experiments.

Table 6. Protein, modified crude fiber (MCF) and total digestible nutrient (TDN) contents for Moapa alfalfa exposed to various air pollutants

	1979*			1980**			1981**		
Treatment	% Protein	% MCF	% TDN	% Protein	% MCF	% TDN	% Protein	% MCF	% TDN
1. Filt.	26.3***	24.3a	52.1	21.4***	27.7a	49.2	21.5***	28.3a	48.7
2. Filt.+SO_2	26.5	22.9ab	53.2	21.8	26.5ab	50.2	21.7	28.1a	48.8
3. Filt.+1AO_3	25.0	23.1ab	53.1	21.8	26.3ab	50.3		(Discontinued)	
4. Filt.+1.5AO_3	26.8	22.2b	53.8	21.1	26.3ab	50.3	22.0	27.9a	49.0
5. Amb.	26.7	23.7a	52.6	22.0	25.6b	50.9	22.0	28.9a	48.2
6. Amb.+SO_2	26.4	23.3ab	52.9	22.1	25.5b	51.0	21.9	27.8a	49.1
7. Outside	25.6	23.2ab	53.0	22.0	26.1b	50.5	22.1	25.4b	51.1
Standard Error	.74	.38		.63	.44		.62	.48	

* Mean for 3 cuttings.

** Mean for 7 cuttings.

*** Treatment means not sharing the same subscript are significantly different at .05 confidence level using Duncan's Multiple Range test.

Table 7. Protein, modified crude fiber (MCF) and total digestible nutrient (TDN) content for WL-512 alfalfa exposed to various air pollutants

	1979*			1980**			1981**		
Treatment	% Protein	% MCF	% TDN	% Protein	% MCF	% TDN	% Protein	% MCF	% TDN
1. Filt.	26.7***	23.0a	53.1	22.6***	26.7a	50.0	22.6***	27.0a	49.8
2. Filt.+SO_2	27.0	23.4a	52.8	23.0	24.9b	51.6	22.4	27.1a	49.6
3. Filt.+1AO_3	26.1	23.0a	53.1	22.3	25.8ab	50.8	(Discontinued)		
4. Filt.+1.5AO_3	27.6	21.7b	54.2	22.1	26.7a	50.0	22.5	27.8a	49.1
5. Amb.	27.0	23.5a	52.7	22.7	26.1ab	50.5	22.5	27.6a	49.2
6. Amb.+SO_2	27.4	22.4ab	53.6	22.8	25.4ab	51.1	22.8	27.1a	49.6
7. Outside	26.5	22.4ab	53.7	22.6	26.0ab	50.6	22.4	25.3b	51.2
Standard Error	.78	.37		.64	.45		.63	.45	

* Mean for 3 cuttings.
** Mean for 7 cuttings.
*** Treatment means not sharing the same subscript are significantly different at .05 confidence level using Duncan's Multiple Range test.

Table 8. Leaf/stem ratios for alfalfa samples harvested in 1979, 1980 and 1981

Treatment	Moapa Variety 9/19/79	Moapa Variety 8/29/80	Moapa Variety 7/27/81	WL-512 Variety 9/19/79	WL-512 Variety 8/29/80	WL-512 Variety 7/27/81
	*	NSD**	NSD**	NSD**	NSD**	*
1. Filt.	1.09a	0.98	0.83	1.09	1.01	0.97a
2. Filt.+SO_2	1.09a	0.95	0.92	1.26	0.91	0.91a
3. Filt.+1AO_3	0.85b	0.85	-	1.04	1.01	-
4. Filt+1.5AO_3*	1.03ab	0.86	0.93	1.14	1.13	0.86a
5. Amb.	1.17a	1.00	0.87	1.16	0.96	0.90a
6. Amb.+SO_2	1.01ab	1.05	1.10	1.12	0.91	1.00a
7. Outside	1.02ab	0.88	1.31	1.01	1.07	1.38b

* Means not sharing same subscript are significantly different at .05 probability level.

** No significant differences using Duncan's Multiple Range test.

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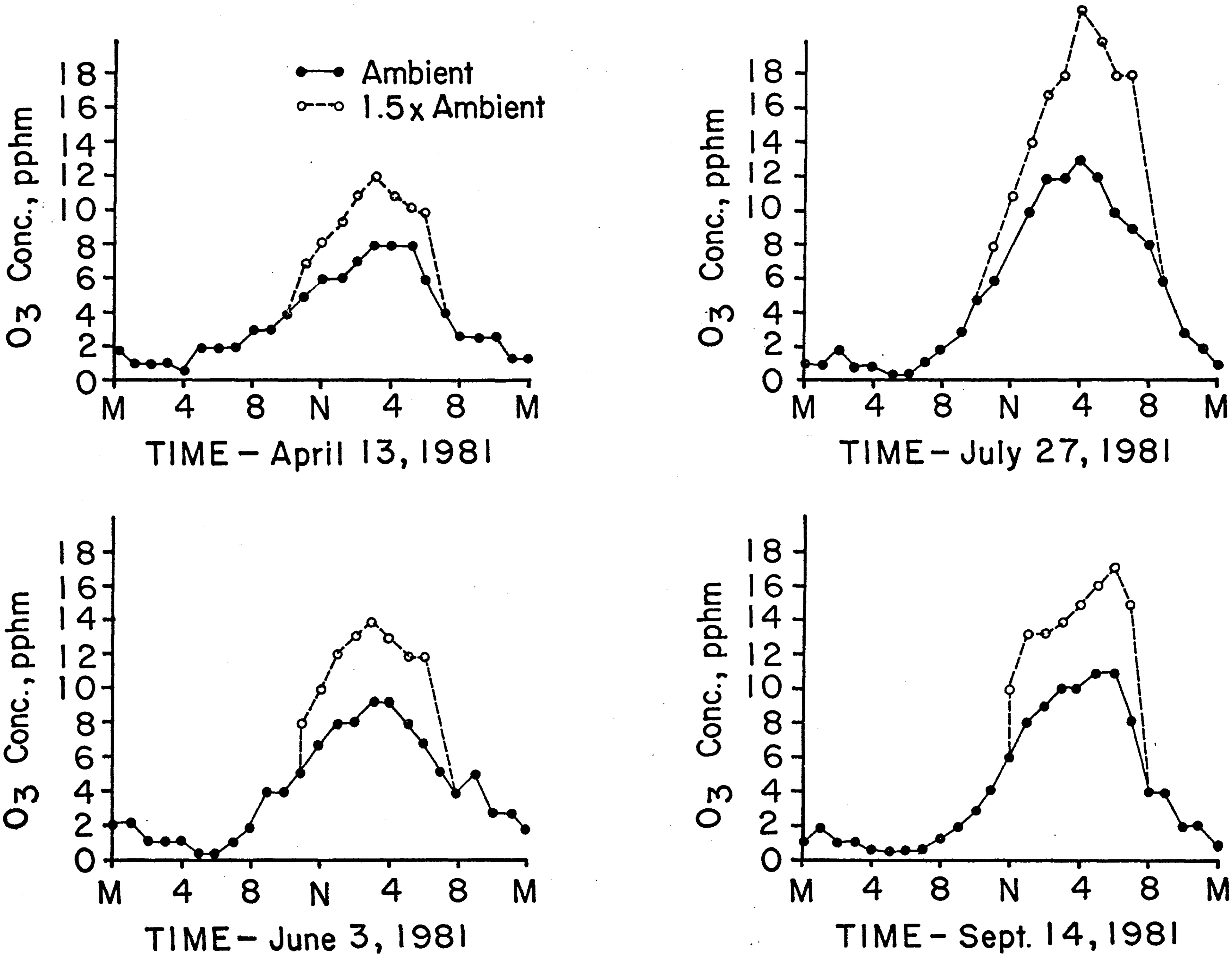
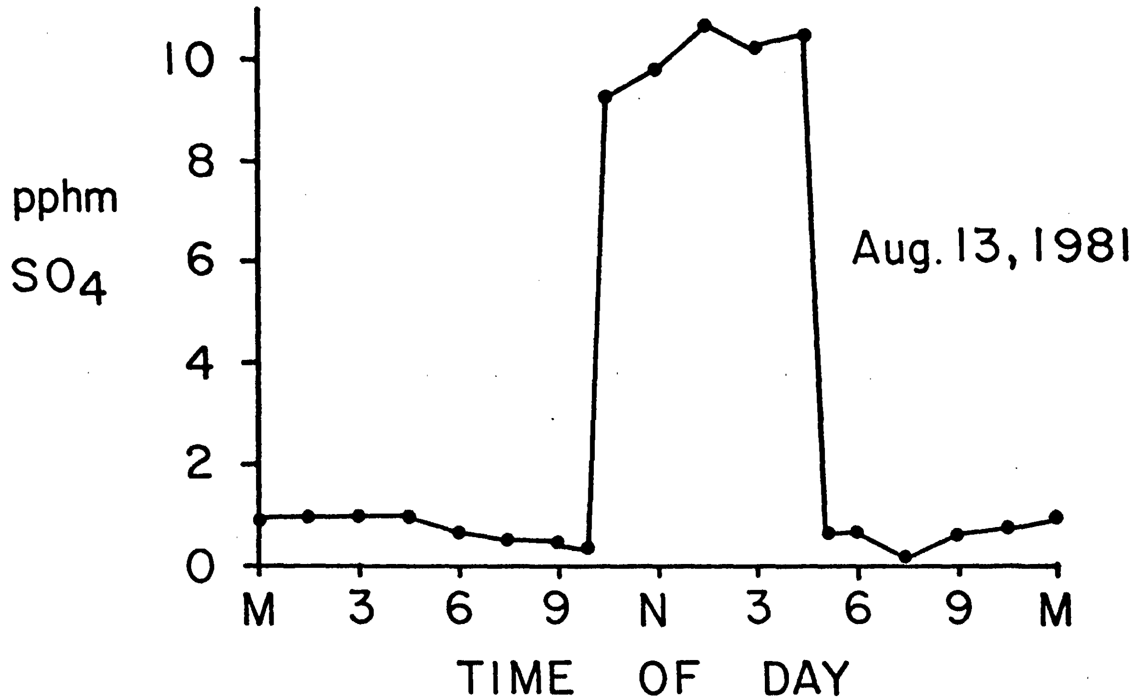
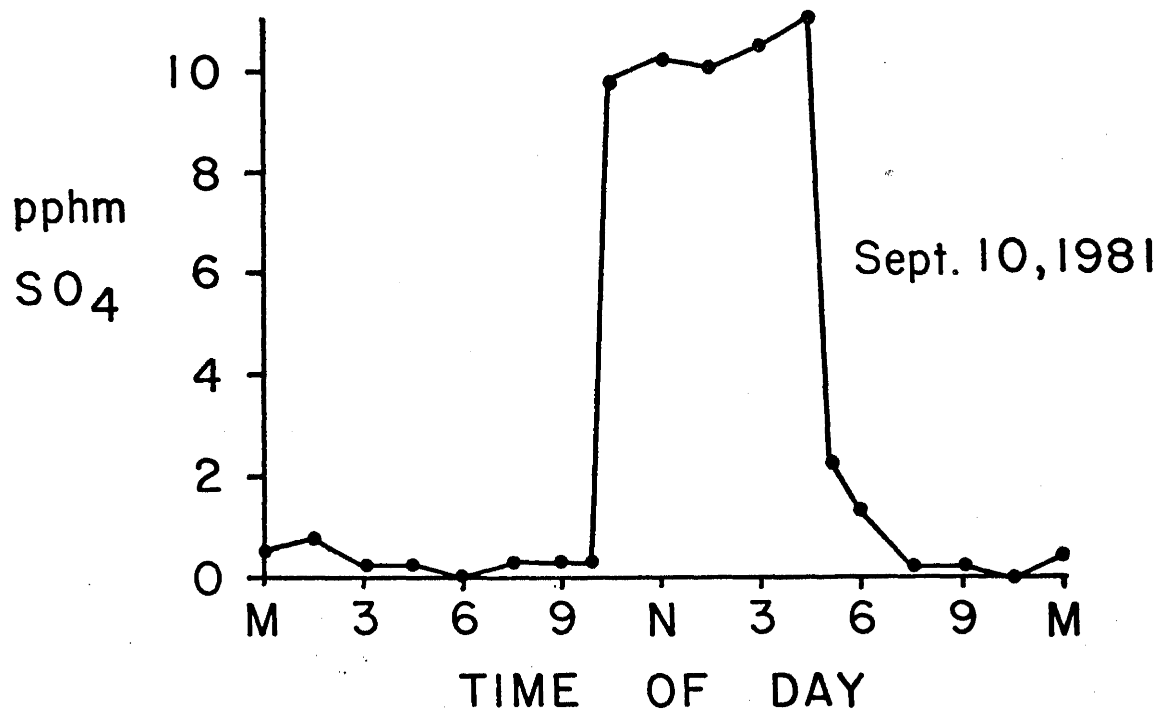
TYPICAL OZONE CONCENTRATIONS



Appendix A



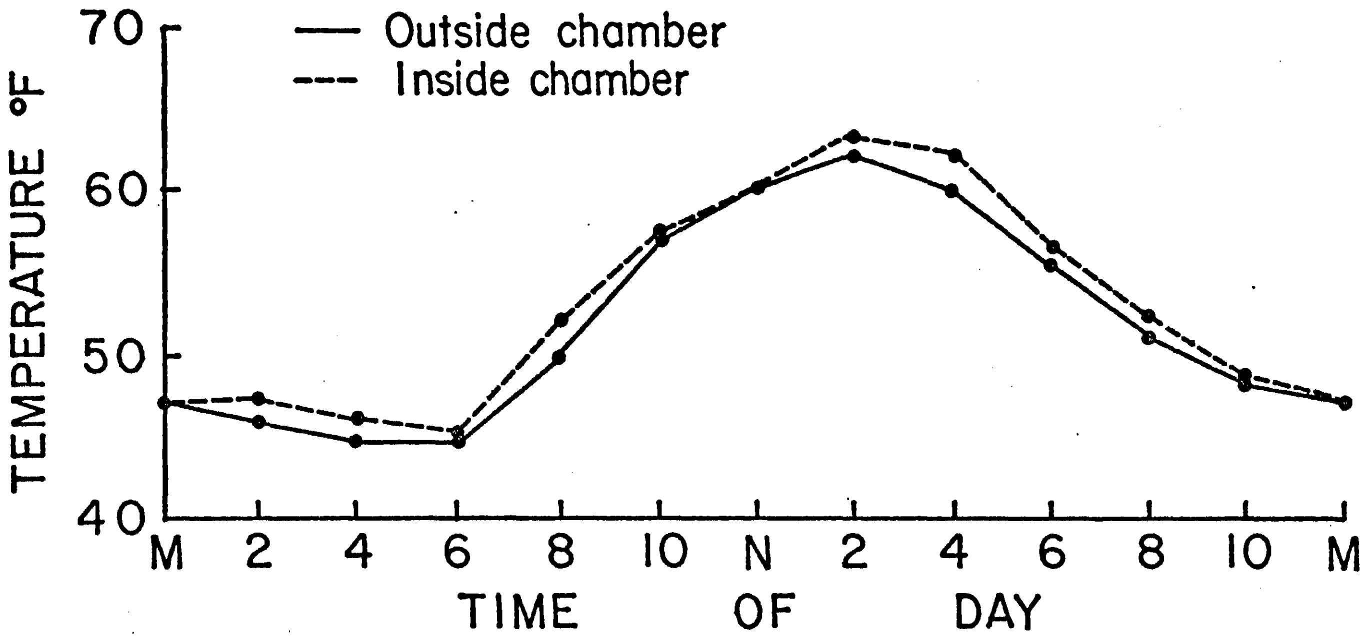
TYPICAL SO_2 CONCENTRATIONS (AUGUST ABOVE, SEPTEMBER BELOW)



AIR TEMPERATURES

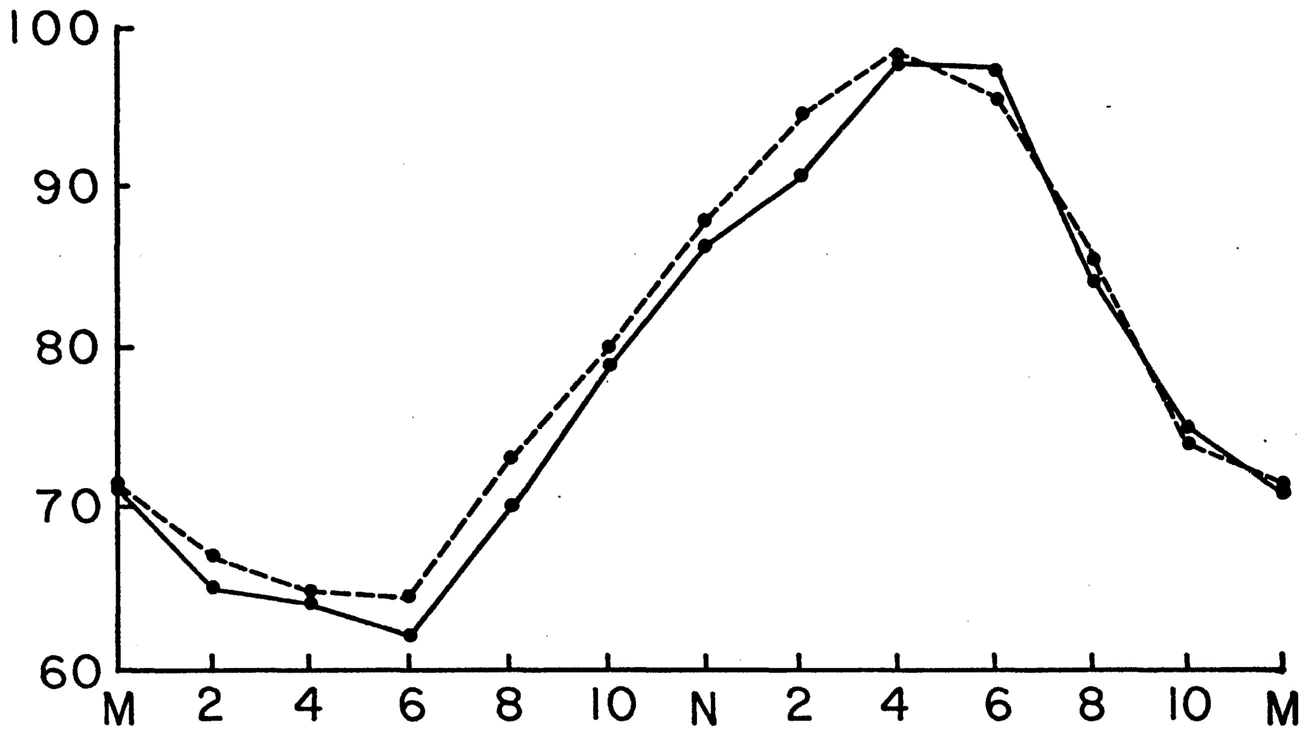
Typical temperatures inside and outside chambers. Points represent average of four days - two days in each month.

MARCH-APRIL 1981

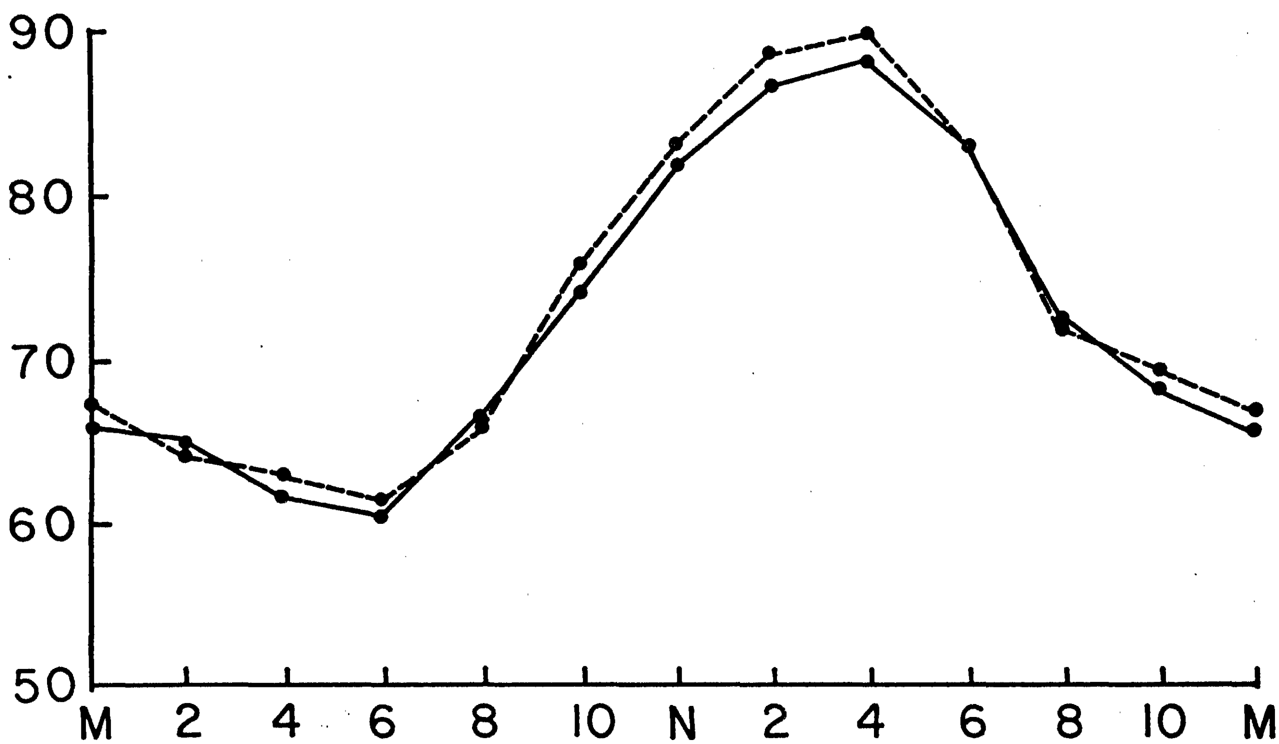


MAY-JUNE

JULY - AUGUST



SEPTEMBER-OCTOBER



Appendix D