REBUILD CALIFORNIA AIR RESOURCES BOARD FIELD FUMIGATION FACILITY AND MAINTAIN FOR EXPERIMENTAL USE

Final Report, February 18 - December 31, 1981
CAL ARB A0-100-32 (Thompson)

C. Ray Thompson
Principal Investigator

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Abstract

The purpose of this study was to rebuild, improve and refurbish twenty greenhouses plus ancillary equipment that was constructed on the Riverside campus in 1977 for the Air Resources Board. By the time the Agreement was signed, another site which had been used by Dr. O. C. Taylor for air pollution studies became available. This newly abandoned site had a fine instrument shelter, power lines installed to 20 greenhouse sites and was located in a level field which had deep soil.

It was decided to give up the original site, salvage as much equipment as practical and construct larger, more versatile greenhouses at the new site. About the same cost would be involved. The former greenhouses provided a total enclosed area of 3.3 M^2 while the new structures have 7.3 M^2.

The new structures are of an original design supported by six galvanized steel tubular posts set in concrete footings. The plastic covers are attached to "polyclip" aluminum circles that are held in the extrusion channels with plastic pipe. The covers are made of two vinyl cylinders. The blowers supply test atmospheres at rates in excess of three changes of air per minute. Two activated charcoal filters provide "clean" air to the system. Flowmeters for metering fumigants into the greenhouses and for measuring samples of the test atmospheres are mounted on panels and a "Scanivalve" which allows rapid sequential sampling from each greenhouse is on hand. Two Thermo Electron SO_2 analyzers and two Dasibi ozone analyzers were used for measuring these pollutants.

Performance of the gas dispensing and analytical system was checked by measuring both SO_2 and ozone in the greenhouses and at the instrument shelter to find out whether absorption or breakdown of the gases occurred in sampling

lines. With SO_2 and ozone, the recovery was essentially quantitative, even though lengths of Teflon sampling lines were considerably different to the individual greenhouses.

Exclusion of outside air at plant height (60 cm) within the chamber was very good with windspeeds up to about 20 mph. Above this level internal mixing of outside air became apparent and levels of dispensed SO_2 and ozone fluctuated widely.

Air temperature comparisons were made inside and outside the greenhouses by shielded thermocouples. Likewise, relative humidity was determined with wet and dry shielded thermocouples. No measurable differences had been observed previously within the chambers between 1/2 and 2.0 m in height. These results show that dry bulb temperatures inside and outside were essentially equal.

Leaf and air temperatures were compared between the different chambers and all were essentially equal.

The mechanics of both gas generating systems and the solenoid controls worked with minimal trouble.

At present the facility has operated for 3 months with no down time, and the experiments in progress are on schedule.

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The purpose of this study was to rebuild, improve and refurbish twenty greenhouses plus ancillary equipment that was constructed on the Riverside campus in 1977 for the Air Resources Board. By the time the Agreement was signed, another site which had been used by Dr. O. C. Taylor for air pollution studies for the Environmental Protection Agency became available because Dr. Taylor decided to move the operation to Shafter, California. This newly abandoned site had a fine instrument shelter, power lines installed to 20 greenhouse sites and was located in a level field which had deep soil.

It was decided to give up the original site, salvage as much equipment as practical and construct larger, more versatile greenhouses at the site formerly used by Dr. Taylor. It was estimated that about the same cost would be involved and would provide a more useable site. The former greenhouses were 2.14 M dia thus providing a total enclosed area of 3.3 M^2 while the new structures are 3.05 M dia with 7.3 M^2 of enclosed space.

The new structures are of an original design supported by six galvanized steel tubular posts set in concrete footings. The plastic covers are attached to "polyclip" aluminum circles that are held in the extrusion channels with plastic pipe. The covers are made of two vinyl cylinders which can be taken off rapidly by removing the plastic pipe retainers. This allows the plastic covers to be stored out of the weather when not in use and in case

of high winds can be removed to avoid major damage. The blowers supply test atmospheres at rates in excess of three changes of air per minute. Two activated charcoal filters provide "clean" air to the system. Flowmeters for metering fumigants into the greenhouses and for measuring samples of the test atmospheres are mounted on panels and a "Scanivalve" which allows rapid sequential sampling from each greenhouse is on hand.

At the abandoned original ARB site the plastic covers, electric wiring, Teflon tubing and items from the instrument shelter have been salvaged. The high capacity blowers will be stored for probable future use, perhaps as part of a linear gradient system for assessing the effects of ambient air pollutants on vegetation.

During the second quarter the greenhouse frames were completed. Plastic sides, doors for access and septum-like tops were constructed and installed on the frames. Blower boxes were constructed, two activated carbon filters were sealed into the framing with foamed neoprene gasketing and the fans were installed. Blower boxes were positioned and attached to existing electrical controls, see photo, Figure 1.

Panels for mounting flowmeters were constructed, flowmeters attached to both SO_2 dispensing cylinders or ozone generator and sampling lines. A Scanivalve with controller was attached to the incoming Teflon sampling lines.

Instruments for measuring SO_2 (TECO) and ozone (Dasibi) were installed, calibrated and readied for sampling.

Mr. Kris Preston and Les Weeks, doctorate and masters degree candidates, respectively, from the Department of Geography at the University of California, Los Angeles under Dr. Walter Westman began fumigation studies with the facility. Several brush species, see attached experimental plan, were exposed in pots.

The highest levels of ozone and SO_2 and the combination caused acute effects, both leaf injury and abscission.

Performance of the gas dispensing and analytical system was checked by measuring both SO_2 and ozone in the greenhouse and at the instrument shelter to find out whether absorption or breakdown of the gases occurred in sampling lines. With SO_2, the recovery was essentially quantitative, Table 1, even though lengths of Teflon sampling lines were considerably different to the individual greenhouses. No systematic differences are shown related to line length. Also, the differences observed are well within the measurement capabilities of the analyzers which are imprecise in the parts per billion range. A similar recovery with ozone was seen but differences are essentially all on the plus side, perhaps because the two Dasibis were not precisely equal in calibration at the beginning or had changed during reinstallation at the two sampling sites, Table 2. Another source of error could be small amounts of ozone leaking by the activated charcoal filters.

Exclusion of outside air at plant height (60 cm) within the chamber was very good with windspeeds up to about 20 mph. Above this level internal mixing of outside air became apparent and levels of dispensed SO_2 and ozone fluctuated widely. During early December a windy period of 3 days occurred with velocities of 35-45 mph. To avoid damage to the chambers the top hoops were lowered to just above the middle hoop. The tops were left as with the full height. As soon as the wind abated measurements of both SO_2 and ozone showed that the levels within the chambers were comparable to those cited in Tables 1 and 2.

Temperature comparisons were made inside and outside the greenhouses by shielded thermocouples. Relative humidity was determined likewise with

wet and dry shielded thermocouples. No measurable differences had been observed previously within the chambers between 1/2 and 2.0 m in height. The measurements were made at 1.5 m ht., Table 3. These results show that dry bulb temperatures inside and outside were essentially equal with this measuring procedure. Relative humidity was increased inside the greenhouses by about 6% by transpiration of the foliage of the experimental plants.

Leaf temperatures of several species under experiment in all chambers were measured by Chris Preston and Les Weeks of U.C.L.A., Table 4. They used the thermistor on a LiCor Diffusive Porometer and took temperature measurements of leaves in full sun at 1500 $\pm$ 50 microeinsteins of radiation. The temperatures of different species differed probably because of ability to reflect sunlight (compare Salvia leucophylla or Artemisia californica with Salvia mellifera), but the leaf temperatures of the first two mentioned species were either identical or varied only one division on the meter, showing conditions affecting leaf temperatures from chamber to chamber were very uniform.

Comparisons were made between the levels of solar radiation within the different chambers and outside. Measurements were made at the 4 quadrants and in the center of each chamber at 1.0 m ht., Table 5. These measurements, taken with a LiCor Model 185A Sensor on Dec. 1, 1981, show reduced light intensities at all quadrants and in the center except the west, because of reflection or shading by the plastic.

The mechanics of both gas generating systems and the solenoid controls worked with minimal trouble. Dust accumulation on the filters in the greenhouses of the sampling lines caused low readings. This necessitated

renewal of the Teflon filters at regular intervals. Air intake filters for the fans also clogged with dust and had to be washed or replaced several times per month.

Presently, the facility has been operating for 10 weeks with no down time. The experiments in progress are on schedule and should be completed by mid-December. After refurbishing filters, cleaning plastic and renewing some damaged ducting, the facility should be ready for Dr. Paul Miller's study in January.

Table 1. Comparison of SO_2 Levels in ppm in ARB Plastic Greenhouses and in Instrument Shelter

Greenhouse No.	Date	Greenhouse	Instrument Shelter	Δ%
18	11-6	.525	.525	0
17	"	.225	.225	0
12	"	.050	.047	-6
13	"	.056	.053	-5
15	"	.055	.058	+5
20	"	.211	.218	+3
10	"	.053	.056	+5
4	11-9	.224	.226	+1
9	"	.053	.053	0
8	"	.239	.235	-2
3	"	.573	.581	+1
6	"	.053	.049	-8

Table 2. Comparison of Ozone Levels in ppm in ARB Plastic Greenhouses and at Instrument Shelter

Chamber #	Dispensed	Greenhouse	Δ%
1	.204	.208	2
2	.204	.203	-0.5
4	.099	.103	4
9	.196	.200	2
10	.089	.100	11
15	.100	.115	13
20	.090	.095	5
19	.350	.352	0.6
14	.095	.100	5
13	.199	.200	0.5
16	.360	.370	3
11	.098	.105	7

Table 3. Comparison of Temperatures and Relative Humidities Inside and Outside Chambers*

	Outside				Inside			
Time	Sensors 1	2	3	Relative Humidity	4	5	6	Relative Humidity
	F°	F°	F°	%	F°	F°	F°	%
November 9, 1981								
10:30	86	87	87	27	87	87.5	87	33
12:30	89.5	90	90	-	89	89.5	89.5	-
13:30	89	90	90	25	89	89	89.5	31
14:30	89	89	88.5	25	89	90	90	31
November 6, 1981								
8:45	62.5	62.5	62.5	-	63.5	63.5	63.5	-
10:00	70	70.5	70	60	69.5	69.5	69.5	66
12:00	72.5	73	73	51	73	73.5	73.5	57
14:00	74	74	74.5	-	74.5	74.5	75	-
16:00	69	69	69	-	70	70	70	-

*Temperatures measured in center of chambers at 1.5 m height; outside temperatures at 1.5 m height and 2.0 m removed from chamber wall to avoid reflected radiation.

Table 4. Comparisons of Leaf Temperatures of Different Species in Experimental Chambers

Chamber No.	Species	Microeinsteins (± 50)	Meter Reading ($\bar{x}$ of 15 leaves) (± 95% C.I.)	Temp. °C
1	Salvia mellifera	1500	62 ± 0.5	38
1	Artemisia californica	1500	61 ± 0.5	36
2	Salvia leucophylla	1500	60 ± 0.5	34
2	Rhus laurina	1500	63 ± 0.5	40
2	Encelia californica	1500	63 ± 0.5	40
3	Salvia mellifera	1500	64 ± 0.5	42
3	Artemisia californica	1500	61 ± 0.5	36
4	Salvia leucophylla	1500	60 ± 0.5	34
4	Rhus laurina	1500	63 ± 0.5	40
4	Encelia californica	1500	64 ± 0.5	42
5	Salvia mellifera	1500	63 ± 0.5	40
5	Artemisia californica	1500	60 ± 0.5	34
6	Salvia mellifera	1500	63 ± 0.5	40
6	Artemisia californica	1500	60 ± 0.5	34
7	Salvia leucophylla	1500	60 ± 0.5	34
7	Rhus laurina	1500	63 ± 0.5	40
7	Encelia californica	1500	64 ± 0.5	42
8	Salvia mellifera	1500	64 ± 0.5	42
8	Artemisia californica	1500	60 ± 0.5	34
9	Salvia mellifera	1500	63 ± 0.5	40
9	Artemisia californica	1500	60 ± 0.5	34
10	Salvia leucophylla	1500	60 ± 0.5	34
10	Encelia californica	1500	63 ± 0.5	40
10	Rhus laurina	1500	63 ± 0.5	40
11	Salvia mellifera	1500	64 ± 0.5	42
11	Artemisia californica	1500	60 ± 0.5	34
12	Salvia leucophylla	1500	60 ± 0.5	34
12	Rhus laurina	1500	62 ± 0.5	38
12	Encelia californica	1500	63 ± 0.5	40

continued

Table 4. (continued)

Chamber No.	Species	Microeinsteins (± 50)	Meter Reading ($\bar{x}$ of 15 leaves) (± 95% C.I.)	Temp. °C
13	Encelia californica	1500	64 ± 0.5	42
13	Salvia leucophylla	1500	60 ± 0.5	34
13	Rhus laurina	1500	64 ± 0.5	42
14	Rhus laurina	1500	64 ± 0.5	42
14	Encelia californica	1500	64 ± 0.5	42
14	Salvia leucophylla	1500	60 ± 0.5	34
15	Salvia mellifera	1500	62 ± 0.5	38
15	Artemisia californica	1500	60 ± 0.5	34
16	Salvia leucophylla	1500	61 ± 0.5	36
16	Rhus laurina	1500	64 ± 0.5	42
16	Encelia californica	1500	64 ± 0.5	42
17	Salvia leucophylla	1500	60 ± 0.5	34
17	Rhus laurina	1500	63 ± 0.5	40
17	Encelia californica	1500	63 ± 0.5	40
18	Salvia leucophylla	1500	61 ± 0.5	36
18	Rhus laurina	1500	64 ± 0.5	42
18	Encelia californica	1500	64 ± 0.5	42
19	Salvia mellifera	1500	64 ± 0.5	42
19	Artemisia californica	1500	60 ± 0.5	34
20	Salvia mellifera	1500	64 ± 0.5	42
20	Artemisia californica	1500	60 ± 0.5	34

Table 5. Percent Outside Radiation in ARB Greenhouses*

Chamber #	North	East	South	West	Center
1	69	69	74	97	74
2	74	69	70	98	71
3	72	73	73	96	76
4	71	73	70	96	73
5	73	71	70	98	76
6	69	69	71	99	70
7	70	70	71	98	76
8	71	70	72	96	71
9	71	71	72	98	75
10	71	74	74	96	71
11	71	70	71	97	73
12	74	72	70	97	73
13	69	69	68	97	75
14	71	72	70	98	73
15	69	69	69	98	74
16	69	69	73	97	73
17	69	71	70	98	73
18	71	71	71	96	72
19	70	69	71	96	73
20	70	70	71	98	73

*1.0 m height
quadrants measured
30 cm from chamber wall

11-12:00 o'clock
Pacific Standard Time

Figure 1. ARB Fumigation Facility at University of California, Riverside, being completed. Note blower housings and activated charcoal filters at right of greenhouse in immediate foreground. All sampling and power lines are installed underground.

Addendum A

Treatments and Measurements to be performed on Brush Species by Kris Preston and Les Weeks

I. Treatments (2 chambers/treatment):

1. Ozone (low) 0.12ppm
2. Ozone (medium) 0.35ppm
3. Ozone (high) 0.50ppm
4. SO_2 (low) 0.03ppm
5. SO_2 (medium) 0.14ppm
6. SO_2 (high) 0.50ppm
7. Ozone (low) + SO_2 (medium) 0.12 ozone + 0.14 SO_2
8. Ozone (medium) + SO_2 (low) 0.35 ozone + 0.03 SO_2
9. Ozone (low) + SO_2 (low) 0.12 ozone + 0.03 SO_2
10. Control (clean filtered air)

Levels choosen correspond to Federal standard levels.
Plants are to be fumigated from 0700 to 1800 hrs. daily.

II. Species to be used:

Artemisia californica, Encelia californica, Eriogonum fasciculatum, Eriogonum cinerium, Lotus scoparius, Quercus agrifolia, Rhus laurina, Salvia leucophylla, Salvia mellifera

Bromus rubens (from clean air site - Santa Cruz Island)
Bromus rubens (from polluted site - Santa Maria Oil Refinery)

In total, 11 species (two Bromus populations), 10 treatments, 5 replicates.

III. Plant-treatment assignments:

- treatments will be randomly allocated to individual chambers
- 5 plant/species will be randomly allocated to each treatment

IV. Pre-fumigation measurements:

1. plant height and width (avg. of min. and max. diameter)
2. no. of flowers per plant
3. basal stem diameter for each plant
4. 2 branches/plant will be randomly picked and tagged, the following attributes will be measured:
   - branch length
   - no. of nodes
   - internodal length
   - thickness, width, and length of 2 leaves/branch
   - stomatal resistance vs. light intensity for 2 leaves/branch (measured at 0700, 0900, 1100, 1300, 1500, 1700 hrs.)
   - 3-5 leaves will be randomly picked from each plant to measure pre-fumigation dry wt.

V. Measurements taken during course of fumigation:

1. repeat pre-fumigation measurements with possible exception of leaf dry wt. (some plants will not have a sufficient no. no. of leaves to sustain this rate of harvesting)
   - measurements will be repeated every two weeks if time permits otherwise every 3 or 4 weeks
2. leaf drop (no. and dry wt. every 2 weeks)

VI. Post-fumigation measurements

1. repeat pre-fumigation measurements
2. assess plant biomass (dry wt.)
3. assess root biomass (dry wt.)
4. analysis of leaf nutrients, protein content, lipid content, and carbohydrate content if funds become available
   - included are; sulfate, total S, Ca, K, N, P, chl a vs. chl b)
5. leaf cross-section to assess cellular damage