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

Final Report

to the

California Air Resources Board

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ABSTRACT

The Statewide Air Pollution Research Center (SAPRC) has had a continuing mission to investigate the effects of air pollutants on both agricultural crops and native vegetation. To further this mission, SAPRC personnel have maintained the California Air Resources Board (ARB) field exposure facilities at the Experiment Station at the University of California, Riverside for over seven years. These facilities consisted of 20 permanent, cylindrical, open-top field chambers for use with low-growing plants; 28 hemispherical, open-top field chambers for use with small trees; and ancillary pollutant exposure and monitoring equipment. The facilities also included a unique field humidification system for use with the cylindrical chambers and a field fog exposure system.

Tasks carried out for the project have included maintenance of all chambers, maintenance of the pollutant exposure systems and analyzers, maintenance of soil and irrigation/fertilization system, acquisition of equipment insurance, provision of field telephone and sanitation services, and assistance to users of the facility. In addition to general maintenance, part of the field site was cleared to grow plants for an ARB-sponsored study of hydrocarbon emissions from vegetation.

The chamber facilities have been used for a wide variety of experiments on the effects of gaseous air pollutants and acidic fog on crops and native plants. This research has resulted in over 25 peer-reviewed publications, reports, and book chapters. Over the past year, a total of five studies were completely or partially carried out in these facilities. ARB-funded studies included (1) a determination of the effects of ambient ozone on Valencia oranges, and (2) an evaluation of hydrocarbon emissions from vegetation. Studies funded from other sources included (3) an investigation on the effects of ozone and sulfur dioxide on quaking aspen and perennial ryegrass, (4) investigation of the effects of ozone and sulfur dioxide on alfalfa, and (5) a pilot investigation of the long-term injury effects of ozone on conifer seedlings.

The intensive use of the facilities continued to indicate the importance and usefulness of maintaining the field exposure facilities in a condition of readiness so that new experiments can be rapidly initiated to address important issues concerning the effects of air pollutants on vegetation.

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DISCLAIMER

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

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SUMMARY AND CONCLUSIONS

The Statewide Air Pollution Research Center (SAPRC) of the University of California, Riverside and cooperating agencies have a continuing mission to investigate the effects of air pollutants on crops, forest species, native herbaceous plants, ornamentals, and all vegetation of importance to California, and to determine the extent of economic loss caused by the pollutants. To accomplish these objectives, it is necessary to have experimental chambers in which plants can be exposed to carefully defined test atmospheres under as close to ambient environmental conditions as feasible. This requires specialized facilities that will (1) exclude ambient air pollutants, (2) provide growing conditions that are as near to ambient outdoor conditions as possible, (3) provide pollutant dispensing and monitoring systems for whatever air pollutant is of interest, and (4) provide for continuous recording of air pollutant levels as well as the important environmental conditions of air temperature, relative humidity, and light intensity both in chambers and outside.

For over seven years SAPRC staff, under contracts to the California Air Resources Board (ARB), have maintained open-top field chambers for both herbaceous plants and trees in an exposure readiness condition which has allowed for rapid implementation of many air pollution studies. The objectives of this project were to (a) maintain all open-top chambers for both herbaceous plants and trees, air exclusion ducts, and fogging systems in top operating condition; (b) assure that all pollutant dispensing equipment such as the ozone generator, SO_2 and/or NO_2 tanks plus temperature controllers, valves, and flowmeters are operating properly; (c) maintain all gas dispensing and sampling lines leak-free; (d) routinely calibrate SO_2, ozone, peroxyacetyl nitrate (PAN), or other gas analyzers; (e) maintain soil free of weeds, provide irrigation and fertilization to chambers; and (f) supervise the use of the facility and provide detailed operating instructions to various investigators so that maximum use is realized.

Supplying basic repair and maintenance services under a single contract has provided for much less expensive operating expenses than if each individual project had to provide air pollutant monitors, calibration services, computer software, site cleanup and preparation, environmental

measurement, and other aspects required for careful air pollution experiments. Supplying assistance from experienced personnel has saved staff time, as well as assured accuracy in operating the facilities. Regular inspection by experienced personnel also enhances the security of the site from vandals and for preventive action against any malfunctions or physical deterioration which may produce damage to these valuable ARB facilities. Basic telephone and hygiene facilities were also needed and used for both sites.

The chamber facilities have been used for a wide variety of experiments on the effects of gaseious air pollutants and acidic fog on crops and native plants. This research has resulted in over 25 peer-reviewed publications, reports, and book chapters.

Tasks carried out for the project over the past year included: (1) maintenance of all chambers; (2) maintenance of the pollutant exposure systems and analyzers; (3) maintenance of soil and irrigation/fertilization system; and (4) provision of assistance to users of the facility. In addition to general maintenance, part of the field site was cleared to grow plants for an ARB-sponsored study of hydrocarbon emissions from vegetation. Another part of the field site was prepared for a possible cotton study in 1989 where the plants will be grown in the ground.

Over the past year a total of five studies were completely or partially carried out in these facilities. ARB-funded studies included (1) a determination of the effects of ambient ozone on Valencia oranges, and (2) an evaluation of hydrocarbon emissions form vegetation. Studies funded from other sources included (3) an investigation on the effects of ozone and sulfur dioxide on quaking aspen and perennial ryegrass, (4) investigation of the effects of ozone and sulfur dioxide on alfalfa, and (5) a pilot investigation of the long-term injury effects of ozone on conifer seedlings.

The intensive use of the facilities continued to indicate the importance and usefulness of maintaining the field exposure facilities in a condition of readiness, so that new experiments can be rapidly initiated to address important issues concerning the effects of air pollutants on vegetation.

Conclusions

(1) Limited funding of routine maintenance for the ARB field facilities at UC Riverside has provided for rapid implementation of new air pollution studies.

(2) Continued use of these facilities has provided for experimental data to answer important research questions as to the effects of ozone, sulfur dioxide, and nitrogen dioxide, and acidic fog on crops and native forest and herbaceous plant species.

(3) Recent modifications of the system provided for experimental plots where plants can be grown in the ground for experimental use.

RECOMMENDATIONS

This project allowed for the effective maintenance of the ARB field chamber facilities for rapid use in air pollution studies. The following recommendations would permit continued effective use of the facilities.

(1) Continued funding at a minimum base level of the most essential maintenance needs required for ARB field facilities at UC Riverside. These would include the 20 permanent cylindrical chambers, 28 hemispherical chambers, and any other ARB-sponsored facilities and equipment.

(2) The funding would cover only day-to-day surveillance for security, insurance costs, and general weeding. The base funding would keep the chambers in a state of readiness for potential studies.

(3) Continued assistance to prospective users of the facilities. This would include scheduling of chamber usage, suggestions regarding design of experiments, and ensuring the facilities are operable over the course of the experiment.

(4) Exclusion of funding in the maintenance contract for needs specific to individual studies. These needs would include new exposure or monitoring equipment, electricity, plant material, insurance specific for that project, unusual fertilization or pest control needs, and any personnel specific for that study.

(5) Additional years of funding would allow enough time to decide the long-term fate of the chambers, including transfer to other sites and/or storage of some components.

I. INTRODUCTION

The Statewide Air Pollution Research Center (SAPRC) of the University of California, Riverside and cooperating agencies have a continuing mission to investigate the effects of air pollutants on crops, forest species, native herbaceous plants, ornamentals, and all vegetation of importance to California, and to determine the extent of economic loss caused by the pollutants. To accomplish these objectives, it is necessary to have experimental chambers in which plants can be exposed to carefully defined test atmospheres under as close to ambient environmental conditions as feasible. This requires specialized facilities that will (1) exclude ambient air pollutants; (2) provide growing conditions that are as near to ambient outdoor conditions as possible; (3) provide pollutant dispensing and monitoring systems for whatever air pollutant is of interest; (4) provide for continuous recording of the air pollutant levels, as well as the important environmental conditions of air temperature, relative humidity, and light intensity both in chambers and outside.

Maintaining the open-top field chambers for both herbaceous plants and trees in an exposure-readiness condition has allowed for rapid implementation of all planned and potential studies. Supplying basic repair and maintenance services under a single contract has provided for much less expensive operating expenses than if each individual project had to provide air pollutant monitors, calibration services, computer software, site cleanup and preparation, environmental measurement, and other aspects required for careful air pollution experiments. Supplying assistance from experienced personnel has saved staff time, as well as assured accuracy in operating the facilities. Regular inspection by experienced personnel also enhances the security of the site from vandals and for preventive action against any malfunctions or physical deterioration which may produce damage to these valuable ARB facilities. Basic communication (telephone) and hygiene facilities were also needed and used for both sites.

Statement of the Problem

It is necessary that all ARB experimental field facilities at UCR be maintained in fully operable condition at all times so that the studies conducted by different individuals are not hampered, nor the results rendered less reliable by equipment or instrument malfunctions. This requires daily inspection of all fans, filters, gas-dispensing systems, and sensing instruments. Concentration of air pollutants must be monitored continuously and analyzers calibrated on a routine basis, or whenever malfunctions are suspected. At the conclusion of any given study, the plastic walls of the chambers must be washed, weeds controlled, any torn or deteriorated plastic replaced, gas dispensing and sampling systems pressure-tested for leaks, flowmeters checked for accuracy, and sensing instruments calibrated. All of these activities are most efficiently and economically handled through a management plan for routine maintenance and operation of the ARB exposure sites.

Objectives

The objectives of this project were to (a) maintain all open-top chambers (for both herbaceous plants and trees), air exclusion ducts, and fogging systems in top operating condition; (b) assure that all pollutant dispensing equipment, such as ozone generator, SO_2 and/or NO_2 tanks plus temperature controllers, valves, and flowmeters are operating properly; (c) determine that all gas dispensing and sampling lines are leak free; (d) routinely calibrate SO_2, ozone, peroxyacetyl nitrate (PAN), or other gas analyzers; (e) maintain soil free of weeds and provide irrigation and fertilization to chambers; and (f) supervise the use of the facility and provide detailed operating instructions to various investigators so that maximum use is realized.

II. FACILITIES

For over seven years the ARB has funded the operation and maintenance of 20 cylindrical, experimental, plastic-covered chambers and ancillary equipment. These chambers are located on the Agricultural Research Station of the University of California in Riverside, and are operated under a contract to SAPRC. The facility has equipment for providing different levels of ambient oxidants and for dispensing controlled atmospheres of ozone, sulfur dioxide, nitrogen dioxide, or other gases to the various chambers depending on the experiment. Figure 1 shows the layout of these ARB-sponsored facilities at UC Riverside.

The chambers are of the basic National Crop Loss Assessment (NCLAN) design (2), with the addition of a diaphragm-shaped baffle at the top to reduce ambient air incursion into the tops of the the chambers (6). The chambers enclose areas of 7.3 m^2, which is adequate for a number of replicate plants for most species. Plants can either be planted in the soil or can be exposed in pots. A watering system can supply the particular irrigation and fertilization needs of each chamber. An instrument building is the location for sulfur dioxide and ozone analyzers, sulfur dioxide flowmeters, an automatic scanning valve for selecting air samples from all 20 chambers, recorders, and the computer data acquisition system.

Recently, a humidification system for use in field studies of air pollution effects on crops has been added to the chamber facility (26). The system involves a full-scale commercial boiler to generate steam, along with ancillary equipment, including propane gas tank and gas handling system, water delivery system to the boiler, ducts to deliver steam to chamber blowers, modified blower boxes, humidifiers for ducts, and humidity monitoring and control instrumentation. Construction of the humidification system added the capability for environmental humidity and possible air temperature control for air pollutant exposures in the ARB chambers. This is the only known field chamber facility with such environmental control in the world. Alfalfa was initially used as a test crop for several experiments to determine the effects of humidification on either acute or chronic ozone effects on plant productivity.

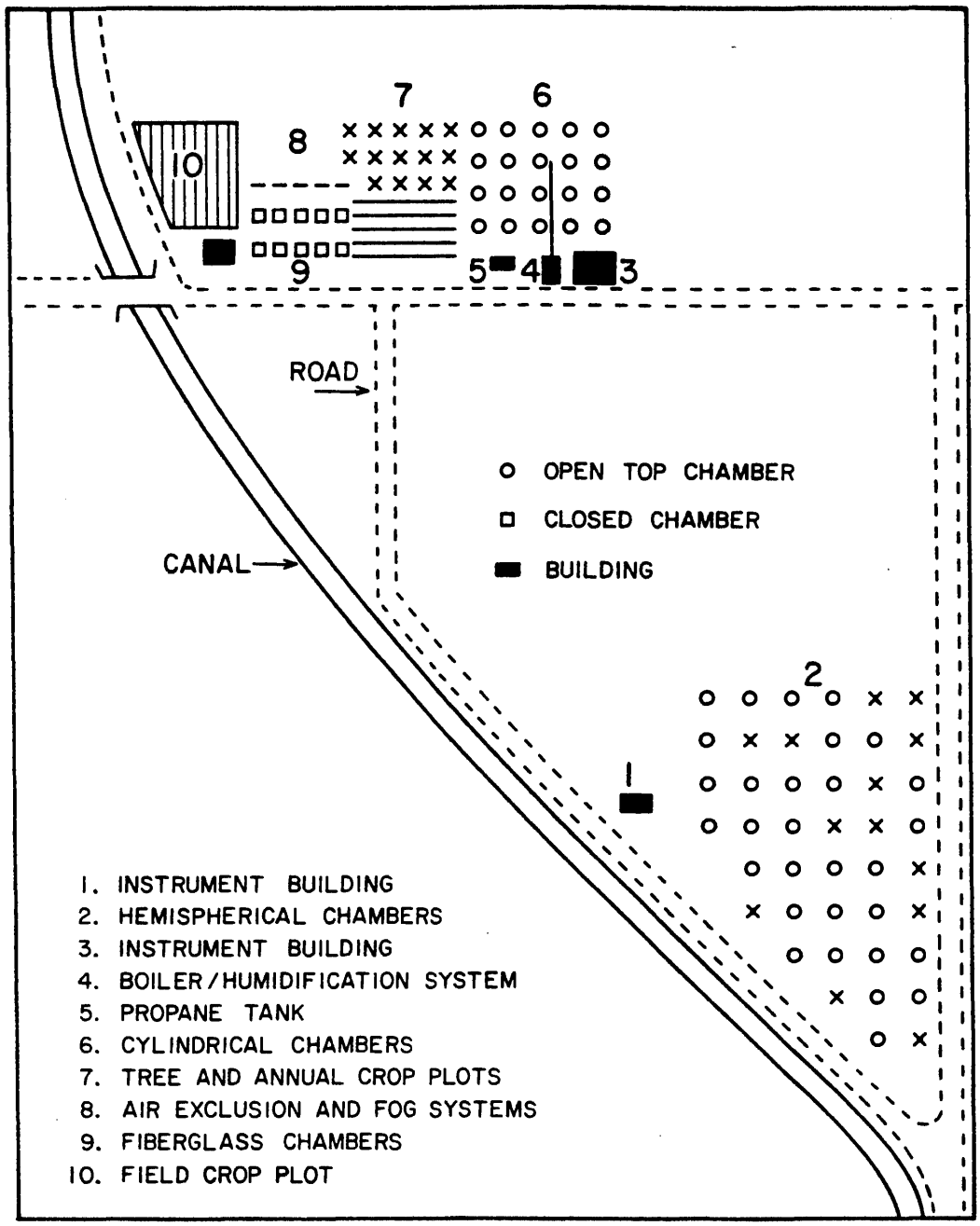

Figure 1. Diagram of experimental facilities and crop plantings.

During the past year, the ARB also funded the operation and maintenance of 28 experimental, hemispherical dome chambers and ancillary equipment for an intensive study on the effects of ozone and sulfur dioxide on Valencia oranges (5,11). All basic maintenance expenses for the orange study have been supplied within the maintenance contract. These expenses have included bulk purchase of charcoal, blower filters, fertilizer, and some pesticides.

Table 1 is a summary of the facilities and equipment at the open-top field chamber sites.

Table 1. Facilities and Equipment at the Field Chamber Sites

For Cylindrical Chambers
20 Open-top field chambers, each 3 m in diameter by 2.43 m in height. The chambers are covered by vinyl and have a cone-shaped baffle at the top to reduce ambient air incursion.
20 Blower assemblies, each consisting of a 1.52 x 0.60 x 0.62 m sheet metal blower box, 3/4 hp ILG propeller fan, fiberglass particulate filter, corrugated activated charcoal filter, and vinyl duct between blower box and chamber.
24 Electrical hookups. There are 20 hookups for the chambers and one each at the locations of four outside plots.
Underground Teflon® air sampling lines to each chamber.
Underground irrigation/fertilization lines to each chamber.
Wet and dry bulb temperature thermocouples to two chambers.
Underground Teflon® tubing for delivering sulfur dioxide or ozone gases to the chambers.
Sulfur dioxide generating system consisting of an insulated galvanized steel can, thermostat and heater for temperature control, tank of liquid sulfur dioxide, mass flow controller and regulators, and heatless air drier to remove water vapor from the sulfur dioxide carrier air. The same system can be easily adapted for nitrogen dioxide.
A heated and air conditioned instrumentation building.

(continued)

Griffin generator and tank oxygen for ozone production.

24-Point scanning valve.

Bendix sulfur dioxide analyzer.

Dasibi ozone analyzer.

Gas chromatograph for peroxyacetyl nitrate (PAN) analysis.

Strip chart recorders.

Cyborg ISAAC® computer interface to process signals from pollutant analyzers.

Apple II+® computer system, including 64K memory, dual disk drive, and monitor for storing air monitoring data.

2 Light intensity sensors.

Dewpoint and humidity sensors.

26 Fog generators plus compressed air delivery lines, chamber tops, and frames for duct systems.

For Hemispherical Dome Chambers for Trees

28 Hemispherical dome, open-top chambers for trees, each 4.27 m in diameter by 3.0 m in height. The chambers have galvanized metal frames, UVEX plastic domes, and fiberglass bases.

28 Blower assemblies for hemispherical chambers, each consisting of a 0.61 x 0.61 x 0.31 m sheet metal blower box, 3/4 hp ILG propeller fan, fiberglass filter, corrugated activated charcoal filter, and sheet metal duct between blower box and chamber.

Underground air sampling, pollutant delivery, and irrigation lines.

Sulfur dioxide generating system.

A heated and air conditioned instrumentation building.

TECO pulsed fluorescent sulfur dioxide analyzer.

Dasibi ozone analyzer.

(continued)

Table 1 (continued) - 2

Strip chart recorders.

Cyborg ISAAC® computer interface to process signals from pollutant analyzers.

Apple IIe® computer system including 64K memory, dual disk drive, and monitor for storing air monitoring data.

2 Light intensity sensors.

Dewpoint sensor.

Additional Facilities Available at UCR

Air exclusion system facilities, gabled fiberglass covered chambers for starting seedling plants, portable NCLAN design chambers, and experimental plots of herbaceous and tree fruit crops.

III. PAST RESEARCH

The ARB-sponsored facilities have been used intensively for a wide variety of air pollution studies over the past seven years. A total of 13 papers have been published to date in peer-reviewed journals based on this research. Results have also been published in three book chapters, 11 final reports, and one abstract.

Future peer-reviewed papers based on this research will focus on the effects of ozone and sulfur dioxide on Valencia oranges, relative humidity, and ozone interactions on vegetation, the effects of acidic fog and ozone on conifers, and the effects of total oxidants vs. ozone alone on alfalfa. The research in the ARB facilities was sponsored by the Electric Power Research Institute, Native Plants Incorporated, and Southern California Edison Company, in addition to major funding from the ARB itself.

Table 2. Summary of Publications Based on Past Research in the ARB-Sponsored Field Exposure Facilities at the University of California, Riverside

Studies	Reference
Acidic Fog + Ozone on Crops and Trees	3,18,21,22-25
Exposure Systems, Techniques	11,12,14
Humidity + Ozone on Alfalfa	26
Ozone on Avocados	20
Ozone, Sulfur Dioxide on Citrus	4,7,15
Ozone, Sulfur Dioxide on Native Annuals, Shrubs and Trees	1,9,10,29-32
Ozone, Sulfur Dioxide on Rice	7,19,27
Ozone, Sulfur Dioxide on Winter Crops	2,13,28
Salinity + Ozone on Alfalfa	16,17

IV. PROGRESS DURING THE CURRENT CONTRACT PERIOD

Task 1 - Maintain and Operate Chambers

Chambers, blowers, duct systems, and fogging systems were maintained in working order. Vinyl plastic was removed from all chamber walls, tops, and ducts. New chamber vinyl was cut to fit and installed as necessary during the year to provide for new studies. The activated charcoal filters for the blowers were checked before each experiment, and removed and refurbished as necessary. Particulate filters were routinely replaced. Other routine maintenance, repair, and cleaning activities were carried out for blowers and chamber doors.

Task 2 - Maintain Air Pollutant Exposure System and Analyzers

The ozone generator and sulfur dioxide delivery systems were maintained in working order. The Teflon tubing and scanning valve system were cleaned periodically to ensure accurate delivery of air samples to the pollutant analyzers. The ozone, sulfur dioxide, and peroxyacetyl nitrate (PAN) analyzers were maintained in working order and calibrated prior to each study. The ozone analyzers were calibrated with a transfer standard ozone analyzer at the South Coast Air Quality Headquarters in El Monte, California. The sulfur dioxide analyzers were calibrated with a standard gas traceable to the National Bureau of Standards. The PAN analyzer was calibrated with a tank of PAN manufactured at SAPRC, with dilutions to equal known PAN concentrations. The Isaac computer interface and Apple computer system was maintained in working order for processing of ozone and sulfur dioxide data. The acidic fog generation system also was maintained disassembled, but is available for use following some reconstruction.

Most air quality and environmental monitoring data were reported in reports for the appropriate studies (e.g., the citrus study final report). The PAN data through May, 1988, were summarized in previous monthly reports for this project. The PAN data were sporadic during the later part of the year due to instrument malfunctions and because the PAN analyzer was being used for other studies. These data are available to the ARB if needed.

Task 3 - Maintain Soil and Irrigation System

The soil both in and around the chambers was routinely weeded. The irrigation system was maintained in a condition for immediate use through repair of tubing and periodic flushing to remove any bacterial buildup.

New plots were created to provide plants growing in the ground for ARB-sponsored studies. These plants provide more natural experimental material than pot-grown plants. One planting consists of herbaceous and woody plants between the cylindrical chamber and fiberglass chamber sites (Figure 1, #7). The land was prepared and five trees each of peaches, (cv. Fay Elberta), almonds (cv. Non Pareil), and nectarines (cv. May Grand) were planted in late spring 1988. Rows of potatoes, lettuce, carrots, broccoli, and spinach were planted in the south end of the plot in August 1988. These species were used for the study of hydrocarbon emissions from vegetation (Dr. A. M. Winer, Principal Investigator) sponsored by the ARB Aerometric Data Division.

The area shown in Figure 1, #10, was prepared for future field plot studies at UCR. This area previously had been used for the ARB-sponsored oxidant study in 1987. At that time, overhead electrical and ozone dispensing and monitoring lines had been installed. However, the plants had been grown in pots buried in the ground.

Task 4 - Assist Users of the Facility

Project staff were available for consultation with any prospective users of the facility. Before each study, basic tasks were carried out to prepare the site for each specific use, including washing of chamber walls, preparation of required fertilizer solutions, and setting up sampling tubes. The pollutant delivery and air monitoring systems were set up according to each user's specifications. Staff was made available on a day-to-day basis for assistance in any operations and repair of malfunctions in instrumentation.

Table 3 summarizes research during 1988 in ARB field facilities at UC Riverside. From November 1987 and terminating in August 1988, 21 hemispherical chambers were used for an investigation of the effects of ambient ozone on Valencia oranges (ARB A7033-87). The treatments during 1988 were carried out with filtered air, half-filtered air and half-ambient air, and ambient air within chambers and with outside control trees.

Land for experimental plantings and buildings were used for an investigation of hydrocarbon emissions from vegetation (ARB A732-155). The plantings were for August-December 1988.

In studies not funded by the ARB, the effects of ozone and sulfur dioxide were studied on quaking aspen and perennial ryegrass (Spring 1988) and alfalfa (Fall 1988, Native Plants Incorporated). A copy of the final report for these projects will be forwarded to ARB staff when available.

In another non-ARB-funded project, seedlings of Pinus ponderosa and P. jeffreyi, were exposed to filtered air, ambient air, half ambient air, and outside air in the hemispherical chambers for several years until August, 1988. The study was a small pilot project without extramural funds.

Table 3. Research Projects During 1988 in ARB Field Facilities at the University of California, Riverside

Project	Facilities Used	Funding Agency
Effects of oxidants on Valencia oranges D. M. Olszyk, P.I.	21 hemispherical chambers, air and environmental monitoring, 12/87-6/89[a]	Air Resources Board
Pilot project on effects of O_3 on tree seedlings D. M. Olszyk, P.I.	Small plants in 15 hemispherical chambers, 12/87-8/88	Pilot Project
Effects of O_3, and SO_2 on aspen and ryegrass A. Bytnerowicz, P.I.	8 cylindrical chambers, 1/88-5/88	Native Plants Inc.
Effects of O_3 and SO_2 on alfalfa A. Bytnerowicz, P.I.	6 cylindrical chambers, 9/88-4/89	Native Plants Inc.
Hydrocarbon emissions from plants A. M. Winer, P.I.	Growing plots and buildings, 6/88-10/89	Air Resources Board

[a]Exposures terminated 8/88, trees maintained through 6/89.

V. FUTURE PLANS

During 1989 and following years the ARB field sites again will be used for several possible projects. All of these are subject to ARB approval and could be replaced by other studies.

(1) Continuing use of crop plots and buildings for the ARB hydrocarbon emissions study through August 1989.

(2) A pilot project investigating the effects of vitamins on ambient ozone injury to plants. Tentative plans call for exposure of herbaceous plants in pots in six cylindrical chambers for three months from July through September 1989 or 1990. The project would be proposed to the Hoffman-LaRoche Pharmaceutical Company.

(3) An investigation of promising current methodologies for measuring plant stress in the field. Several new instruments would be tested including a new chlorophyll fluorescence meter, a calorimeter to measure respiration, and a "red edge" reflectance analyzer. The study would use approximately eight cylindrical chambers for three months from June through August. The project will be proposed to the Air Resources Board.

As there will be no maintenance contract after June 30, 1989, specific contracts with any agency must include funds for all aspects of each project. These include: (a) all electrical costs for blower operation and instrumentation in control buildings; (b) costs for pollutant analyzer repairs calibration, and new instrumentation; (c) pollutant gas tanks, oxygen tanks for ozone generation, acidic fog solutions, and all other pollutant generation needs for specific studies; (d) supplies for physiological and biochemical measurements; (e) telephone, insurance and portable sanitary facilities; and (f) costs involved with plant material including seed and seedling costs, specific soil or pot needs, fertilizer, pest control and weed control.

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