DRAFT FINAL REPORT

A DEMONSTRATION OF THE EFFECTS OF SMOG ON ORNAMENTAL AND HOME GARDEN PLANTS

CONTRACT A733-138
CONTRACT A833-137

Prepared for the Air Resources Board by the

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NOTE TO READERS: ERRORS

Pending review and comment by ARB staff and the Research Screening Committee on this draft report, differences in the size, placement and errors in the sequencing of the page numbers in the draft report's Appendix will be corrected. The draft report does not contain Appendix pages with the numbers 97,135,137,154,165,166, and 167; however the contents of the pages are the actual signs which will be installed in the Greenhouse exhibit in April, 1991. The sequence is correct as mis-numbered. The Appendix contains a Page 58 and a 58B; since both photographs reproduced well, one of these pages will become 59, and the appropriate adjustments will be made to the numbers to following pages. If the quality of these back to back photocopies are acceptable, the numbering layout will be adjusted accordingly and the temporary numbers will be replaced with camera-ready ones.

The text for the top photograph on page 26 will be corrected so that "backrop" reads "backdrop." The text on page 28 will be corrected so that the word "geedback" reads "feedback." The text on Page 46 will be corrected so that " are too large have more" will read "are too large to have more." The text on Page 73 will be corrected so that "Coreiander" will be spelled "Coriander." Page 60 will be corrected so that "Necotiana" will be spelled "Nicotiana." All the footnotes on the charts on Pages 77 to 86 will refer to the date as 1990, [the exposure/response time frame] rather than as "90-91" [the funding time frame]. Page 130 will be corrected so that the title reads "Scarlet Sage," rather than "Scarelt Sage."

Page 191 has the pictures which belong to Page 192, and visa versa. The Page number will be switched. The chart on page 63 will have the date 1990 removed from the title because the same types of symptoms are seen each year.

Other typographical errors will be corrected. Please accept the apologies of the authors, editors, and word processors.

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SUMMARY

The California Air Resources Board and the Los Angeles State and County Arboretum funded the Air Pollution Greenhouse display to increase public awareness of the effects of existing air quality on plants commonly found in yards and gardens in the greater Los Angeles area. A home and its yard and garden represent major investments for owners. Programs to provide clean and healthy air are expensive and require extensive public support to be successful. If the program to clean up the air is perceived to benefit the home owner, it is more likely that people will be cooperative and supportive as the control program rise in cost and impact more and more of people's everyday living activities.

Over 140,000 visitors have seen, touched and smelled plants grown in a filtered air greenhouse and compared their appearance with the same age and type of plant grown in a matching layout in a greenhouse containing ambient air. From children to adults, students to scientific researchers, home gardeners to landscapers--all have had their knowledge about air quality enhanced by a tour through the Air Pollution Greenhouse.

The Air Pollution Greenhouse is a working research facility which provides a controlled environment in which to grow ornamental and home garden plants. Over 100 varieties of plants have been grown under identical environmental conditions except for air quality. Many exhibit a syndrome of air pollution injury symptoms. The most common effects have been pale or yellow leaves and other color changes; leaf spots which vary in size and severity; reduced size and number of leaves, flowers or fruits; reduced growth and vitality and a shortened life span for different plant organs or for the entire plant. Some other effects have been reduced resistance to insect pests and a smaller root system. Previous research on the impact of pollution on ornamental plants has demonstrated acute visible damage such as leaf spots, but no publications are available which include more than a few examples. In this project, photographs taken every two weeks against a standard background. These photographs have been used to document the response of vegetation in the Air Pollution Greenhouse. Comparable information on other types of ornamentals is not available.

The Air Pollution Greenhouse facilities consist of a greenhouse divided into two sides, one of which is equipped with charcoal filters to remove air pollution. Air quality monitoring equipment is installed and documents that the clean air side of the greenhouse is free from measurable amounts of ozone and oxides of nitrogen, two pollutants known to create air pollution injury to vegetation. Air pollution levels in the unfiltered side of the greenhouse vary with the season. The exhibit also includes an Information Center with information oriented to the general public and covering such topics as how air pollution is formed, what effects it has on people and vegetation. Information is provided on what can be done to reduce pollution. Tour guides, posters, a slide show and brochures are used by the visitor to learn to recognize air pollution symptoms. The visitors are then encouraged to tour the greenhouse display and identify the symptoms on the plants in the greenhouse. Some of the plants in the greenhouse always show air pollution symptoms. Prior to the time of year when the smog levels are high enough to cause air pollution symptoms, a fumigation chamber is used to provide plants with air pollution damage.

The response of the public to this display has been excellent and extensive coverage has been provided by area television stations, large circulation newspapers and popular magazines.

A comprehensive program has been undertaken to upgrade the display, in response to visitors comments and requests. The staff of the Air Pollution Greenhouse have learned that it is not enough to provide the public with a simple greenhouse containing plants. Air pollution symptoms are difficult to recognize and modifications to the display have been required to make it possible for visitors to recognize the damage. The improvements required included big, easy to read signs and examples of what to look for on the plants. Photographs which clearly illustrate the symptoms are hung over every plant in the exhibit, prompting the viewer to look for specific symptoms. The same information must be provided in different ways. Visitors prefer to see pictures of the plants, rather than read about them. If a real plant is displayed, the visitors prefer that to the picture. A slide show is preferred to wall charts and posters, but displaying the air quality monitor without wall charts and posters to explain it is confusing. Staff has applied the standard teacher's formula of "Tell them what you are going to tell them, tell them the information, and tell them what you just told them. The combination of this tech-

nique and the same type of scientific design criteria used in other types of research on the impact of air pollution on vegetation have made the Air Pollution Greenhouse Exhibit a success.

Many requests been made for copies of the photographs, but providing them to all who ask is clearly beyond the scope of this project. A questionnaire was used to evaluate visitor satisfaction; over 95% rated the exhibit as informative and interesting. Many left the display concerned about the problems of poor air quality and perhaps more willing to do something about improving it.

RECOMMENDATIONS

This project is successful in meeting its goals to provide an informative and thought provoking display on the adverse effects of poor air quality on garden variety plants and it has provided a unique and useful body of information on a group of plants not previously studied. The Air Pollution Greenhouse Display should be enhanced by the implementation of the following recommendations, and should receive continued funding and support from the Air Resources Board and the South Coast Air Quality Management District beyond the 1991 smog season.

Vegetation

1. The 1990 greenhouse display should include at least 20 plants which respond to ambient air pollution with outstanding examples of air pollution injury symptoms. Include at least 40 plants about which nothing is known about their sensitivity to air pollution. Label these clearly as "test" plants and encourage the visitors to evaluate them for air pollution symptoms. The greenhouse display should continue to contain a supply of plants fumigated in the on-site fumigation chamber; some of the test plants should also be fumigated to verify the symptoms seen are ozone-related.

2. Plants chosen must grow well in a greenhouse environment and be tolerant of higher levels of humidity and temperature and of limited growth space.

3. Plants chosen must have high resistance to common greenhouse diseases and pests which produce symptoms which can be mistaken for air pollution injury.

4. Plants should be kept to a size which is convenient to photograph as documentation of the air pollution injury; trees in particular, cannot be taller than the ceiling in the Information Center's photography studio.

5. Plants not grown from seed at the Arboretum should be personally selected by the Air pollution Greenhouse staff so that the plant pairs are introduced when they are of identical appearance.

Facilities

6. Reduce the temperature in the ambient side of the greenhouse to below 90^0 by additional cooling. White wash or screening can be used. If necessary, the cooling equipment should be upgraded.

7. Establish a schedule for application of pesticides and try a wider variety of pest controls, such as long term ant poison or sticky fly traps. Investigations on plants which have become severely infested should be terminated; a more frequent replacement of batches of plants may be necessary.

8. Increase readiness to deal with breakdowns by obtaining a supply of plastic air tubing and keeping it in the greenhouse ready for instant repairs. Routinely check air coolers and clean the filters on the air conditioner frequently.

9. Implement a dust control program to protect sensitive electronic equipment and reduce the amount of dust on the plants as a means of combating insects and diseases. Sweep the Information Center daily; replace the dusty gravel walkways with cement or similar material. Enclose some of the equipment with dust protecting boxes, such as the slide projector.

Information Center

10. Further improve the displays in the Information Center with new posters targeted at children. Prepare the new posters used last year in a "final version" with enhanced graphics.

11. Continue to emphasize the "What I did to improve the air today" Poll in the Information Center.

12. Improve the photography of plants by using more lighting, have all print and slide development done by one vendor. who can deliver the best and most consistent color and tone.

13. Improve the standard background used to photograph the larger plants by enlarging the signs identifying the plant name, date, location and type of exposure.

14. Identify some of the outstanding display plants and produce a series of photographs which demonstrate growth

reductions.

15. Improve the signs in the greenhouse and the Information Center which use photographs by having them ready to install when the exhibit opens, and distinguish between the standard "display" plants and the new "test" plants.

16. Provide photographs of the greenhouse in operation, the responses of the visitors, the activities of the photographer and other "location" shots which will be required for brochures or other outreach materials.

17. Install the computer to record, store, and display air quality readings before the smog season starts, so that correlations can be made between the onset and severity of symptoms and air quality dose.

Services to Visitors

18. Have 10,000 copies of brochures and handouts available at the start of the display season, especially brochures from the South Coast Air Quality Management District.

19. Expand the program to attract visitors to the display by increased publicity. Notify area media sources about the display and follow up press releases with phone calls. Invite service organizations in the community to see the exhibit and to bring their families. Members of these organizations are active in community affairs, but may not have environmental concerns as their goal.

20. Call attention to the location of the exhibit to visitors arriving at the Arboretum. Make information about the exhibit available to staff who answer phone inquires and give tram tours.

21. Upgrade the slide show with introductory and transitional text slides and make copies available to ARB, SCAQMD, UCR and other educational institutions. Any photographs delivered should be clearly labeled and organized in date order for each type of plant.

21. Prepare to publish a brochure or booklet about the display which includes photographs.

ACKNOWLEDGMENTS

We would like to take this opportunity to acknowledge the efforts of the following people for their support of "A Demonstration of the Effects of Smog on Ornamental and Home Garden Plants":

Dr. Homero Cabrera, Air Resources Board, for his support since the beginning of the project to 1988.

Mr. John Jung, Air Resources Board, for installing, up-grading and maintaining the air quality monitors each week, and explaining how they work.

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Mr. Ken Quigley, Arboretum Volunteer, for the photography.

Ms. Gloria Shams, Head Plant Nursery Worker, who planned and set up the greenhouse, maintained the display vegetation, and managed the visitor response questionnaire and the photographer during the 1988 display season.

Ms. June Petrie, Student Worker, for staffing the greenhouse from April 4, 1989 to May 7, 1989 and for report writing, 1989.

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Ms. Connie Randles, Student Worker, for staffing the greenhouse from April 1, 1989 to May 7, 1989.

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Mr. Joe Williams, Air Pollution Greenhouse staff, for assistance with maintenance of the display plants from April 20, 1990 to October, 1990.

Ms. Mary Abney, Arboretum Plant Nursery Worker, for advise on caring for the plants and in assistance with pesticide use.

The many visitors who took time to answer the questionnaires, so we could improve the displays.

Mr. John W. Provine, Arboretum Superintendent, for overseeing this project.

This report is submitted in fulfillment of the Air Resources Board Contract #A733-138 and Contract #A833-137: "A Demonstration of the Effects of Smog on Ornamental and Home Garden Plants," by the California Arboretum Foundation, under the sponsorship of the California Air Resources Board. The Display was operated between April 1, 1988 and October 31, 1988; between April 1, 1989 and October 31, 1989; and between April 5, 1990 and October 31, 1990

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 sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products."

ABSTRACT

The Air Pollution Greenhouse Display, funded by the Los Angeles State and County Arboretum and the California Air Resources Board, increases public awareness of the effects of existing air quality on plants commonly found in yards and gardens in the greater Los Angeles area. Over 140,000 visitors have seen, touched and smelled plants grown in a filtered air greenhouse and compared them to the same age and type of plant grown in a matching layout in a greenhouse containing ambient air. Because horticultural practices and environmental conditions are the same in both greenhouses, differences in appearance are due to air pollution levels in Arcadia. Air quality is monitored and displayed. Tour guides, posters, a slide show, and brochures identify symptoms, provide information on causes and effects of air pollution, and identify how individuals can improve air quality. A fumigation chamber provides plants with air pollution symptoms during the entire display season, April through October. Over 100 types of plants have been displayed and screened for air pollution sensitivity from 1987 to 1990. Little is known about the sensitivity of these plant species. Photographs taken every two weeks document air pollution injuries which are a syndrome of symptoms, including pale leaves, leaf spots, leaf drop; reduced fruit and flower quality and production; changes in color and shape of the entire plant; reduced growth and shortened life spans. Coverage by area television stations, large circulation newspapers and popular magazines have informed hundreds of thousands more people.

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Page 208: Title page for Copies of Signs Used in Greenhouse to Help Visitors Recognize Air Pollution Symptoms. Pictures were taken in 1989 and Signs Were Displayed in 1990.

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INTRODUCTION

The Air Pollution Greenhouse at the Los Angeles State and County Arboretum in Arcadia, California, is a display designed for the public to see, touch, and smell popular ornamental and home garden plants growing in smoggy ambient [outside] air and compare them to the same age and type of plant grown in clean, filtered air. Their visit provides them with firsthand evidence on the decline in the health of ornamental vegetation due to existing levels of air pollution.

Poor air quality is as much a part of a Southern Californian's way of life as is the famous sunshine. During the summer months, smog updates and alerts are a frequent addition to weather reports. During peak pollution periods, the elderly and children are advised to avoid extended periods out of doors in the middle of the day. It is not surprising that residents of the nation's most polluted air basin are perhaps more aware of the dangers posed to human health from air pollution than on the effects of air pollution on plant life.

Anyone who has taken a class in science is taught that human beings and other animals are totally dependent upon plants for their survival. However, it is difficult for people living in a high pollution environment to know what healthy plants should look like in the absence of the air pollution. It is difficult to understand the decline in the health of ornamental vegetation or agricultural crops if the evidence of the harm cannot be recognized. A home and its yard and garden represent major investments for owners. Programs to provide clean and healthy air are expensive and require extensive public support to be successful. If the program to clean up the air is perceived to benefit the home owner, it is more likely that people will be cooperative and supportive as the control programs rise in cost and impact more and more people's everyday living activities.

Working together, the California Air Resources Board [ARB] and the Los Angeles State and County Arboretum [LASCA, or the Arboretum] have provided an exhibit demonstrating the impacts of air pollution on commonly grown ornamental and garden plants. The Los Angeles State and County Arboretum plays an important role in the conservation and perpetuation of our natural resources. As a depository of

plants representing the past, the present, and the future, the Arboretum has collected and introduced plants from around the world. A primary goal of the Arboretum is to discover plants that are horticulturally suitable for Southern California. Therefore, the Arboretum has a keen interest in air pollution because it could limit or prevent the use of a desirable plant species. The California Air Resources Board is equally concerned with the vulnerability of plant life in the face of air pollution. In addition to its regulatory programs designed to reduce pollution to levels which do not harm human health and welfare, the Air Resources Board disseminates information about air pollution and its impacts on the health of human beings and on vegetation. Likewise, through its exhibits, displays and other activities, the Arboretum disseminates information to the public about plants, their environment, and their importance to people. From their common goals of increasing public awareness, the Arboretum and the Air Resources Board set out to provide a display of the effects of air pollution on the homes and gardens of residents of Southern California.

The Air Pollution Greenhouse was designed to demonstrate that air pollution is a problem right in people's own yards. In response to visitor's comments on the visitor's questionnaire, improvements have been made in the display arrangements, the type of educational material provided, the graphic signs, charts, photographs and other presentations in the Information Center portion of the display.

This report is intended to give the reader a description of the establishment and operation of the Air Pollution Greenhouse display, of the response of the plants in the display to ambient air pollution, and of the response of the visitors to the display. To our knowledge, the Air Pollution Greenhouse is the only exhibit of its kind, and is a source of unique information for those concerned with air pollution.

The report contains one "Appendix," which is 259 pages of photographs, charts and figures, arranged so that the reader will receive a "picture" report on the project. All page number references in the text portion of this report refer to pages in the section containing the pictures, charts, and figures. Pages 1 to 19 serve as an introduction to the display. Pages 27 through 58B illustrate the methods used to improve the operation of the exhibit. Within this section, Pages 29 to 34 illustrate improvements made to the Information Center; Pages 35 to 43 illustrate improvements made to the green-

house portions of the display; and Pages through 49 indicate improvements in the operation of the display. Pages 49 to 60 illustrate how changes in photography are used to document the growth of the plants and improve the display by serving as a teaching tool to help the visitors recognize air pollution symptoms on the vegetation. The next section documents the results of the exhibit. Pages 61 to 223 illustrate the response of the vegetation in the display. The remaining pages illustrate the response of the visitors. Pages 223 to 230 contain the results of the questionnaire filled out by the visitors, and Pages 231 to 249 illustrate the responses of the media and the outreach program.

DESCRIPTIONS OF THE DISPLAY

The purpose of this portion of the report is to describe the exhibit. Pages 1-27 are the companion illustration pages for this portion of the report. The Greenhouse structure and facilities will be described. The report will describe the contents of the displays housed by the facilities. First the display in the Greenhouse will be covered; then the display in the Information Center will be described.

The Air Pollution Greenhouse Facilities

In 1987, the Air Pollution Greenhouse Display was constructed on the grounds of the Los Angles State and County Arboretum, in Arcadia, California. It is located near the entrance at the edge of the South African Section where water and electricity are available. Visitors to the Arboretum receive a map which shows the location of the exhibit, and large signs direct visitors who approach on foot. The conductors of the tram also point out the location of the greenhouse. Page 4 is a map which shows the location of the air pollution greenhouse display. Photographs of the structures making up the Air Pollution Greenhouse Display can be seen on Page 6.

The Air Pollution Greenhouse is 33 feet by 35 feet, divided into two sides by a glass wall. A potting area and an Information Center connect to the greenhouse area, and together these facilities make up the structure of the display. Page 5 is a drawing of the floor plan of the exhibit, showing the relative location of the greenhouse, the potting area and the Information Center. The greenhouse was designed to grow plants in environmental conditions that match as closely as possible those found in home gardens and yards in Arcadia from the

months of April through October. As shown in the photographs on Page 6, the greenhouse is equipped with air coolers and dust filters to maintain temperatures below 80°F during the day and above 55°F at night. One half of the greenhouse is equipped with additional carbon filters to remove ambient air pollution. The lower picture on Page 7 is a photograph showing the location of the charcoal filters and coolers which remove pollution from the "filtered" side of the greenhouse, providing the "clean air."

The greenhouse benches and floor planting areas on each side of the Greenhouse are arranged in a image of each other, separated by a wall which has a glass top half. This design enables the visitors to see matched pairs of plants and compare their appearance under both exposure conditions. Page 9 contains photographs which shows the mirror image layout which permits the visitor to stand in front of a particular plant and look across the greenhouse, through the glass wall and see the same plant grown under the other air pollution exposure conditions. Page 14 is a photograph showing the visitors in the filtered side of the greenhouse, looking at the vegetation on the benches (right side) and the floor area (left side). The "smoggy" side of the greenhouse is on the other side of the glass topped wall, on the far left of the picture.

Contents of the Display's Greenhouse

During 1987, the first year of operation, over 40 species of popular ornamental and home garden plants were grown in each half of the greenhouse. When the greenhouse was set up for the first year's display, very little information was available on what type of plant would make a good display of the range of air pollution symptoms. Therefore, the first season's operation was a test of different species most likely to respond to air pollution. The layout of the first plants selected is shown in the drawing on Page 10.

Changes have been made in the plants displayed from season to season based on the evaluation of the responses of the first plants in the display, and on the basis of visitor requests and questions. The plants were also selected on the basis of their ability to adapt to greenhouse conditions and to withstand common greenhouse insects and pathogens. Selections of plants were made from those which are commonly grown in yards and gardens in Southern California, so many visitors would come to the exhibit thinking they already knew what a healthy plant should look like. Since very few people have ever

seen plants growing in filtered air, even the most sophisticated visitor can be presented with something "new." Each display season, additional ornamental plants are added to the display and screened for their response to air pollution. To date, 73 additional species of plants have been tested and evaluated in the greenhouse for their response to air pollution. Pages 11, 12, and 13 are the layouts of the plants displayed in 1988, 1989, and 1990. The 1990 display included 81 different species of plants in each side of the greenhouse. Since growing conditions in the exhibit are carefully controlled, the information about the air pollution sensitivity is useful to the academic and regulatory communities.

Contents of the Display's Information Center

Recognizing air pollution damage to vegetation requires a "trained eye" to distinguish its effects from similar symptoms caused by disease organisms, insects, nutritional disturbances, insufficient water, or senescence [old age]. Therefore, visitors are provided with information about air pollution and its effects in an effort to help them recognize air pollution symptoms on display in the greenhouse. This portion of the display is contained in the Information Center. Visitors to the Information Center see explanatory materials on wall posters, an air pollution monitor with all of its parts labeled, a display of real time air quality, and printed materials on the impacts of air pollution on human and vegetation which visitors could take home. The 1990 display in the Information Center included a slide show made from the photographs taken the first three years. Although all the vegetation inside the greenhouse portions of the display have labels pointing out the type of damage, additional special exhibits are set up in the Information Center to help the visitor recognize symptoms of air pollution. Pairs of plants are removed from the greenhouse, or special plants are grown for this purpose. These special exhibits have varied from season to season and are discussed in further detail in the methods and results section of the report.

Page 15 is a drawing of the floor plan of the Information Center. It indicates that the wall to the right of the main entrance is lined by storage cabinets. The top of the storage cabinet provided a counter top where handouts and information are placed, where the air pollution poll was conducted, where the side-by-side display of living plants showing symptoms are located, and where the slide projector display was installed. The wall opposite the main entrance contains wall posters, the free standing display on the impacts of air pollu-

tion on agriculture, and provides storage for the oxygen tank used in generating ozone. The wall to the left of the main entrance permits the installation of an information table and provides the standard background for the photographic studio, and has space for the air quality monitor. Page 17 is list of the wall posters used in the Information Center between 1987 and 1989; Page 18 is a list of the new posters added in 1990.

The reactions of the viewing public were assessed by their responses to the tour guides and to a brief questionnaire. Page 224 includes a chart showing the text of the questionnaire which was placed next to the exit from the display. Response to the questionnaire was excellent, and many useful comments were obtained. Improvements have been made to the display in response to the completed questionnaires.

Description of the Program to Attract More Visitors

A public outreach program was started in the second display season, to attract more visitors to the display. Coverage was obtained in popular magazines and large circulation newspapers. This coverage included photographs of the more dramatic responses of the vegetation to air pollution.

Description of Photography

There are no recently published technical publications available which document the response of ornamental and home garden plants to air pollution over a period of time. What little was available usually showed one or two photographs, to illustrate the kinds of symptoms associated with ozone exposure. These symptoms ranged from areas of leaves with dead cells (called "lesions" or "spots") to changes in color, shape and size of flowers or of the entire plant. Nothing is presented to indicate the order in which the symptoms might appear, or what the range of expression of any single type of symptom might be. Most of the documentation in the air pollution research literature is on injury symptoms and growth reduction on valuable agricultural crops. However, even this type of photograph of the air pollution injury symptoms makes a good tool with which to recognize air pollution symptoms. Even if the viewer is familiar with what a healthy plant should look like, responses to environmental conditions, insects and plant diseases can make the diagnosis of air pollu-

tion injury a difficult task. Teaching the general public how to recognize air pollution symptoms requires more than a few pictures; this exhibit provides a range of tools to permit the visitors to observe both excellent examples of air pollution damage and plants on which the damage is just emerging. The exhibit presents the same information in different ways: in text form, in the form of living plants, in the form of samples taken from living plants, and in photographs. The photographs permit the visitor to focus on what specific symptoms should look like and form the basis upon which the comparisons are made.

The first photographs taken of the plants in the display were used to document the arrangement of the display and as a general guide to the Arboretum staff tending the display. As they became available, photographs were included in the Information Center to help the visitors recognize air pollution symptoms. Many of the visitors made positive responses to photographs. Therefore, a program was begun to photograph selected plants at a two week intervals. By the third year of the display, enough of these photographs were available to be added to the labels in the greenhouse. During the third display season, resources were devoted to making a photographic record of the growth of all the plants in the greenhouse. Photographs were taken at regular intervals of the same pairs of "test plants", for the duration of the display season. As the number of visitors seeing the photographs in the display or in the publications grew, more and more requests were received for copies. However, there were no funded program elements included in this project to make these photographs available to the general public at anywhere near the level of demand. Over 100 requests have been received by the Arboretum staff in 1990 for "information about the display, including photographs."

This report contains photocopies the photographic record made of the responses of the plants, from page 24 through 222 of the Appendix. In order to produce the quality of photography required to document the range of symptoms seen in the display, especially changes in growth, a photographic studio was constructed in the Information Center. Just as the facilities provide a standard background from which the visitor makes a comparison of plants grown under the different levels of pollution, a standard background was required for the photographer. Including the same standard background in all photographs released from this project will prevent misunderstandings about what the photographs show, especially for

people who have not seen the exhibit. Both slides and prints were obtained, all of which indicate the species, the location, the date, and which of the pair of plants shown was grown in the smoggy side of the greenhouse and which was grown in the filtered side.

These photographs were used to create a preliminary version of a slide show. The slide show was tested in the Information Center in 1990, and visitor response is being used to upgrade this presentation. Our photographs represent a unique documentation of the impact of air pollution on ornamentals as well as a tool to help the visitor interpret what the plant's response to air pollution looks like.

OBJECTIVES

The purpose of this project was to provide the public with an opportunity to learn to recognize the adverse impact of air pollution on common ornamental and garden plants and to provide the academic and regulatory community with information on a group of plants not previously studied.

The same experimental design criteria used in other air pollution research projects involving vegetation were used in this project to construct and operate a greenhouse. The Museum quality signs, displays and other educational tools were applied to the greenhouse setting to make the "experiment" [in the case of this project, the "demonstration"] easy to understand by a visitor coming to the research location. The difference between the results from this project and other research projects funded by the Air Resources Board is that one of the "deliverables" is turning the research itself into an exhibit open to the public while the work is in progress. Because the work has extended over several smog seasons, the demonstration of "work in progress" has been able to use the previous year's work to capture the demonstration in other media, such as the collection of slides and photographs, that take the viewer on a tour of the exhibit.

The filtered side of the green house is used as the "control" to demonstrate that the changes in vegetation are due to the "experimental variable," which is the ambient levels of air pollution. The Information Center portion of the display was oriented to the general public and covered such topics as how air pollution is formed, what effects it has on people and vegetation, and what can be done to reduce it. An outreach

program was designed to attract visitors to the display and educational materials have been created for those who can not attend. The means to duplicate and distribute these materials is not fully established at this time.

METHODS

The methods section of this report will document how the greenhouse portion of the display was operated, how the exhibits in the Information Center were expanded and improved, how the public reaction was sampled, how the photographic studio was designed and operated, and how the public outreach program was designed and operated. Photographs illustrating the methodology used can be found on Pages 19 through 60.

The Air Pollution Greenhouse demonstration was based on the assumption that if pairs of plants are grown in identical circumstances except for their exposure to air pollution, any differences seen would be attributable to the air pollution. Finding a match between symptom seen from exposure to ambient air with symptoms produced on previously symptom free plants from the clean air circumstance is the final step in confirming that the effect seen is related to the exposure to air pollution rather than to insects, pathogens, or other variations in the environment.

The method chosen to demonstrate the impact on air pollution was to design a greenhouse in which the only experimental variable that was not kept the same for both pairs or sets of plants was air quality. The exhibit contains two categories of plants: the "display" plants which do exhibit air pollution symptoms, and "test" plants, about which not much is known concerning their response to air pollution. These plants are labeled with signs which read "????". These test plants are listed in the tables of "Suitability Trials" which can be found on Pages 64,67,70, and 73. The visitors coming to the exhibit are taught how to compare the appearance of these test plants with the display plants. The exhibit also contains other educational materials which the visitor uses identify air pollution symptoms. Thus, the visitor is invited to become involved in the experiment rather than just being a passive observer.

The success of the project is measured by the actions and written responses of the visitors and by the re-actions of

the plants documented by photographs and written logs. Changes were made to upgrade the display based on the responses of both the plants and the public, so that the maximum amount of public awareness was obtained.

Each display season, the staff of the Arboretum followed a work plan to make it easier for the visitors to see how air pollution damages familiar plants. In 1986-1987, under ARB Project A5-145-33, the project was designed, the greenhouse and information center were constructed and operated, and modifications to improve the exhibit were begun. Each "smog season" thereafter, the display facilities and the contents of the display have been improved. The specific details of the construction of the display, the maintenance of the display, and the changes made in the operating procedures for each display season follow.

Construction of the Display Facilities

Construction began on July 6, 1986 in the Arboretum's South African Section, a site located a short walk from the entrance to the Arboretum. An existing building, 13' x 18', was remodeled to house the information center; an existing, but hazardous, greenhouse was torn down to make room for the display greenhouse. This new greenhouse was constructed by California Greenhouse Controls Corporation. The 33' x 35' Estate Style Twin Ridge greenhouse was divided into two sides by a glass topped wall. The layout of the greenhouses was designed so the public could stand in front of a particular plant and look through the center glass wall and see the same plant growing in the other half of the greenhouse. A floor planting area was planned and custom benches were designed and constructed according to this plan. These benches can be seen in the picture on Page 8. Construction was completed in February, 1987, and the exhibit opened to the public for the first time on April I6, 1987.

The greenhouses were designed to keep the inside air at the same temperatures and relative humidity as the outside air. This design factor was critical to the display because plants often grow differently in a typical greenhouse environment. the goal was to produce a display in which the plants looked as if they were growing in someone's yard. Cooling equipment was selected which could maintain the greenhouses below 85°F during the day and above 55°F at night. The carbon filtered, or "clean air" side of the greenhouse has

two coolers equipped with carbon filters and dust filters. Each cooler is rated at 5500 CFM and is equipped with a .5 horsepower 2 speed motor and a 115V pump. Page 7 shows a picture of the equipment required to clean and circulate the air in the greenhouse. Each cooler is housed in an air tight sheet metal housing box made of 16 gauge galvanized sheet metal. Both boxes were painted inside and out with one coat of zinc chromatic primer and one coat of heavy duty machinery enamel. Sheet metal ducts were used to connect each cooler box to an opening in the greenhouse wall, where four-way air control grills were located. Ozone, nitrogen oxides and other pollutants were removed from the outside air by four W-45 carbon filters housed inside the cooler box and protected from large dust particles by pleated dust filters. All the boxes housing filters are sealed with "closed cell" neoprene weather stripping. The control system is set at "low" speed for maintenance operation, and is switched by means of a thermostat to "high" speed when the cooler pump is turned on to cool the greenhouse. The pumps keep the entire greenhouse under "positive pressure" so that even though the doors are opened as the visitors move from one side of the greenhouse to the other, polluted air is pushed out of the filtered side of the greenhouse. Air is circulated within the greenhouse by means of plastic tubing "ducts" suspended near the ceiling. One of these ducts can be seen in the picture on Page 9. Exhaust air relief is provided by 4 oz. barometric shutters located as high as possible in the gables of the roof.

The non-filtered side of the greenhouse [also described as the "smoggy" or ambient side] is equipped with two coolers, pumps and dust filters. Page 7 contains a picture of this equipment. The coolers are rated at 4000 CFM, and are equipped with .33 horsepower single speed motors. A thermostat control provides cooling upon demand, just as in the other side of the greenhouse. The dust filters are "Poly Media" in ziplock holders. The same type of plastic tubing circulates air within the greenhouse, so that each side has the same degree of air mixing.

The remodeling for the Information Center consisted of installing a new ceiling, removing windows, and installing inner walls to link the building to the greenhouse. The Information Center is shown in the pictures on Pages 15-18. An air conditioner was added to maintain the temperature required by the air pollution monitoring equipment provided by ARB. Pictures on Page 30 indicate the location of the monitoring

equipment and the air conditioner from 1986 to 1987. Wall posters were designed and prepared by ARB staff and installed behind plexiglass sheets. Eight panels made up the first Information Center Display: Air pollution and Plants, Air Pollutants that Damage Plants, The Air Pollution Triangle, sources of Air Pollutants That Form Ozone, Geography and Air Pollution, Climate and Air Pollution, Air Pollution Damage to Plants, and What You Can Do About Air Pollution. These wall charts are shown on Page 31 and 32. The staff of the California Air Resources Board furnished brochures which were made available as handouts: "How Air Pollution Damages Health," "California's New Smog Check Program," "Acid Precipitation in California," and "The Effect of Smog on California Plants."

Maintaining the Display's Facilities

Maintenance for the air coolers and filters consists of changing the dust filters in March, before the greenhouse is opened, and again in July, or more frequently depending on how dirty they get. Both motors and pumps require periodic service and replacement when breakage occurs. The first air conditioner installed in the Information Center had to be replaced in 1989. During the winter months when the air pollution levels are not high enough to cause visible symptoms to the plants, the exhibit is closed to the public and used to "over-winter" some of the valuable vegetation in the Arboretum. Taking down the display, and cleaning and fumigating the greenhouse prior to re-opening the exhibit in the early spring are the other periodic maintenance chores required.

During the first display season, no maintenance problems were encountered beyond what were considered the initial adjustments of the equipment.

During both the 1988 and the 1989 display seasons, the air quality monitoring equipment required frequent repairs and service by the ARB staff based in El Monte. A weekly inspection and service schedule was set up in the 1990 season which prevented the monitors from being out of service and contributed greatly to the morale of the staff running the exhibit.

Electrical problems with the swamp coolers were experienced in April, September, and October of 1989 on the unfiltered side of the greenhouse. Modifications were made in the electrical service to accommodate the installation of the photography studio, as indicated in the picture on Page 23.

The air quality monitoring equipment was moved. During the 1990 display season, the motor and pump from one of the coolers on the non filtered side failed and was replaced in July. A two-month delay was encountered in obtaining a supply of plastic tubing. Any broken tubing should be repaired immediately, especially on the filtered side of the greenhouse.

In the 1990 season, when the ambient temperatures exceeded 100°F, the coolers were not able to maintain the temperatures in the ambient side at the same levels as those in the filtered side. The vegetation experienced heat stress severe enough to adversely impact its display quality. Additional cooling will be needed on the ambient side of the greenhouse during the 1991 season. The best alternative seems to be the installation of a lime white wash on the glass to keep temperatures inside the greenhouses below 90°F.

Maintaining the Vegetation Display

The purpose of this section of the report is to discuss the methods used to set up and maintain the display of vegetation.

It is not an easy task to maintain a display of plants so that some are always showing air pollution symptoms clearly. Because the Arboretum presents plants to the public looking their best, the staff not accustomed to display plants with spotted and dead leaves. Care was taken to train the staff to prune he plants in both sides of the greenhouse to an equal degree. Greenhouse conditions also encourage a variety of insects and plant pathogens. The response of the plants to insects and pathogens can be confused with those responses typical of air pollution. Because of the numbers of young people attending the exhibit, a program to use "beneficial" insects to eat the "pest" insects was attempted each display season. In practice, in a greenhouse, biological control of pests is not that easy to accomplish. Spraying with Safer soap, washing the insects off each of the plants was not successful. Finally, to save the plants in the display, the application of chemicals of minimal toxicity to people were required to control the pest infestations. The chemicals used and their application dates for the 1990 display season are listed on Page 48. Despite repeated attempts to display certain plants, the problems with aphids and whiteflies on these plants compromise the health of the other plants in the display and their inclusion is not recommended.

1987 Display Season's Methods

The plants included in the first season's display are shown in the layout on Page 10. The majority of these plants were started from seed in the filtered side of the greenhouse, and were planted only once. When the plants were big enough to be transplanted to 4" or larger pots, half were moved into the un-filtered side of the greenhouse and half remained in the filtered side. Ten plants of each type were included in each side of the display. Pinto beans, asters, sunflowers, marigolds, and bush peas were planted twice; radishes and cucumbers were planted three times. At the end of the display season, eleven of the 26 types of plants showing air pollution injury symptoms were judged the best examples of air pollution symptoms.

Some of the plants were selected because they would readily show acute leaf injury symptoms following an air pollution episode. Others were chosen as an example of an overall reduction in growth. However, the first year of the exhibit did not make this distinction clear to the visitors. Some of the plants could replace air pollution damaged leaves, so they were not always display-quality examples of acute leaf injury, particularly at times when there were no high hourly ozone readings. Rather than discarding these plants and replacing them with younger and more vulnerable plants of the same species, they were removed from the benches and used to fill in spaces in the floor display. This practice resulted in a very full greenhouse, and prevented the visitors from clearly seeing the range of symptom expression. The picture on Page 36 indicates how abundantly the plants grew in the filtered side of the greenhouse. The staff focused on keeping the plants appropriately watered and fertilized, and did not groom them to "show quality". In contrast, the staff maintaining the display in the second season were determined to keep the display looking neater. As a consequence, they tended to pick all the dead leaves off the plants, including the ones that had been killed by the pollution.

1988 Display Season's Methods

The layout of the greenhouse display for the 1988 Display is drawn on Page 11. It is the same layout used during the first display season. As before, the plants were grown initially in the filtered side so that they were free of ozone injury when they were placed in the display. In response to the many

requests for roses, miniature roses were added. A rose grower donated *Cecile Brunner, Honest Abe cv. Aaron* and *Beverly Hills cv. Delmatore*; *Prima Donna*, a pink rose bush, was purchased locally.

An attempt was made to increase the staffing so that someone was available to the visitors all the hours the display was open. Problems were encountered due to the high turn-over of college student employees. It was difficult to find the type of employee who was willing to care for the plants and stop work to greet the visitors and conduct tours. Some of the display plants were overly groomed so that it was impossible to see injury symptoms. An attempt was made to re-plant some of the display so that a constant supply of plants which responded well to "episodes" of pollution would always be present in the most vulnerable portion of their life cycle. Some of these plants were changed too often to permit the pollution symptoms to develop.

Another problem encountered was insects. An attempt was made to use an integrated pest management program, but the beneficial insects were not received from the vendor in time. The problem with white flies and spider mites was not controlled until the end of the season, after repeated spraying. During this display season, most of the improvements were focused on the facilities and on the Information Center, in response to the visitor comments.

1989 Display Season's Methods

The visitor surveys indicated that the changes made to the Information Center the previous season had been helpful, so the focus of the improvements returned to the plants themselves. The layout of plants for the display is shown in the drawing on Page 12. Changes were made in the methods of displaying the plants in the 1989 display season to emphasize the difference in the types of air pollution symptoms that occur after pollution episodes and after a season-long exposure to various levels of pollution.

All but two plant selections in the shrub and tree area were replaced with new species. The two retained plants were *Vitis cv. Fredonia* and *Washingtonia filifera*, because they were excellent examples of air pollution damage. The California Fan Palm was of particular interest to the plant scientists at U.C. Riverside been unable to test the leaf injury symptoms referred to them for a diagnosis of air pollution. This tree was

planted again to confirm that the symptoms seen the previous year were due to air pollution. Pictures of the response of this plant can be seen on Pages 46 and 47. Since the visitors continued to request additional roses, five hybrid teas and two miniature rose bushes were added to the shrub and tree area. Eleven new vegetables and bedding plants were introduced in the 1-gallon sized section of the display. These changes reflected the display's dual function as a place to educate the public and a facility to test the impact of air pollution on plants not previously observed.

The most significant change in the display was the attempt to help the visitor distinguish between responses to "episodes" of pollution and the response to a season-long exposure. Most of the non-woody plants are more vulnerable as younger plants. Many of the plants displayed on the benches were propagated from seed and the plants in the display area were restarted on an ongoing basis. Other plants that were started anew throughout the season were those which reached senility sooner, and exhibited the most dramatic symptoms of damage later in their life cycle.

For example, the bush bean, *Phaseolus vulgaris*, was extremely sensitive to pollution in its first four weeks of growth. On the filtered side, the early bush bean plants were vigorous and lush with deep green leaves. On the unfiltered side, the same aged plant was markedly smaller with brown, beige and black spots on the leaves. Approximately three weeks later, plants on both sides of the display had borne their bean crop and would start to decline. The bush beans on the unfiltered side declined more rapidly, but a plant in decline in the clean air side perplexed many of the visitors. It was decided to eliminate all the "older" examples of bean, except for the one or two plants kept for the effort to photograph each type of plant through its life cycle. Thus, the display of beans consisted of plants that were approximately four weeks old, with only two out of the 10 plants permitted to grow through their entire life cycle. The beans were removed from the display at about 6 weeks of age, and replaced with younger, more vulnerable plants.

In theory, the new plantings were to be started in the filtered side of the display. Space limitations did not allow for a nursery area, and the cool nights in the early part of the summer would have inhibited seed germination. Therefore,

seeds were started in the Arboretum's propagation greenhouses, which were not filtered but provided the required warmth. It normally took a week to 10 days for the various seeds to germinate. Ten days later, they were transferred to two-inch pots, and after another week of acclimation, they were moved to the filtered side of the Air Pollution Display greenhouse. Every effort was made to bring the two-inch-potted seedlings into the filtered air as soon as possible. As soon as the pollution damage became noticeable, the new plants were put in place of two to four of the older plants. The older plants were discarded in the case of the vegetables; in the case of the flowers, they were donated to charity groups. This shift-and-discard process enabled the visitors to have some excellent examples of the response of plants to short term exposures to high levels of pollution, but required advanced planning, additional space, and more detailed record keeping on the part of the staff.

The benches were could accommodate eight 1-gallon plants per plant variety, which is an adequate number of plants for a tightly designed scientific investigation. Two out of the eight plants of each type were designated test plants. To document growth changes in these sets of tests plants, they were labeled as either the "A" or "B" test batches and were photographed every two weeks of the season-long exposure. The other plants were subjects for the shift-and-discard process, when the replacement plants were big enough to transfer to four-inch pots. This time frame was different, depending on the growth rate of each type of plant. At any one time, each side of the display would consist of at least 4 one-gallon sized pots and 4 or more 4-inch sized pots. The filtered side also had a collection of 2-inch pots of replacement plants. At least four individuals of each type of plant remained in the greenhouse for the duration of their seven-month "summer" development.

The entire crop of *Phaseolus vulgaris, Raphanus sativus, Zea mays* and *Dahlias* had to be restarted twice, due to their rapidity of growth and decline. The entire crop of *Cucumis sativus* and all the other Cucurbita plants and the *Solanum melongena* plants were restarted because they became infected with powdery mildew. The *Brassica oleraceae*, both broccoli and cauliflower, were restarted also due to pesticide damage. Valuable information was gained on which plants needed to be replaced more frequently, and which could be counted on to remain longer and still be excellent examples of the symptoms of air pollution.

1990 Display Season's Methods

The layout of the 81 plants selected for display during the 1990 season is shown in the drawing on Page 13. Once again, the maintenance involved the selection of suitable plants, care of the plants (watering, fertilizing, grooming), elimination of insect pests, and replacing old or dead plants with young plants.

Plants were selected in early March, and the majority were grown from seeds ordered from Park Seed, Greenwood, SC. Selected larger plants, including shrubs and trees, were purchased from local nurseries, just as the home owners do. Careful selection was made at such nurseries as Armstrong and Monrovia for plants of identical size and shape. This selection is best done by the display staff who understand the critical nature of the selection process. As it has since the display opened, the Arboretum provided pots, potting soil, and fertilizer. The seeds were germinated as before in the Arboretum nursery. The warm moist environment hastened the germination. The local shopping expedition and the use of the Arboretum nursery permitted the display to open with large healthy plants in place.

As before, when the seedlings were large enough to tolerate the cooler temperatures, they were brought to the filtered side of the greenhouse. When they grew to 4-inch pot size they were allocated to either the filtered side or the ambient side. As before, between three and eight individuals of the same type were placed on the greenhouse benches. Trees and large shrubs planted in the bed had only one specimen per side, due to space limitations.

The larger plants displayed in the bed were retained in their 5-gallon containers for the first time. Large holes were dug in the greenhouse and 10 gallon containers were submerged. The 5-gallon containers were then set into the submerged containers in such a way that the plants were properly at ground level and the space between the containers was filled in, as shown in the picture on Page 8. This method is commonly used in pollution chambers to give the experimenter access to the plants for observations. For the first time, the larger plants could be removed for photographs being taken on a regular basis to record any growth differences.

All the plants were watered at the same frequency as their species required. Once a week a one-half dilution of

water soluble 20-20-20 fertilizer was applied. Grooming the plants involved removing spent flowers and dead portions of the plant. Smog damaged leaves and flowers were left on the plants for purposes of the display. Because plants were photographed for overall growth, trimming was kept to a minimum and care was given so that both sets of plants were trimmed equally. When the summer temperatures rose too high for the greenhouse coolers, many of the cool season plants showed considerable heat stress. Cucumbers, lettuce, viola, primrose and begonia died and were replaced by younger plants or dropped from the display.

Again, the most difficult aspect was keeping the plants free from insect pests. Infestations were often recurrent, despite the attempts to control the pests with beneficial insects and sprays. Late April brought the arrival of aphids and ants. The aphids suck out plant juices, stunt new growth and cause the foliage to pale, curl, and die. They secrete honeydew, which in turn attracts ants and encourages black sooty mold. The staff was able to wash the aphids off and control the populations by spraying the plants with Safer Soap. Other insect pests were not controlled by the Safer Soap, and at times the greenhouse portion of the display was closed to the public for the application of pesticides.

Spider mites and whiteflies were the most difficult to eliminate, and caused the most physical damage to the plants. The photographic record being kept made it imperative to preserve the same plant specimen for each session of picture taking. Most methods of eliminating spider mites and whiteflies were effective for only 2 weeks. The worst pest infestations occurred during July and August, the peak period of visible smog damage to plants. Very few visitors could distinguish between the insect damage and the smog damage. For this reason, the application of pesticides is more beneficial to maintaining the display than the use of only the integrated pest management system which relies on beneficial insects to kill the insect pests. The demonstration is on the smog damage, not on the method of pest control. As in the past, it was noted that the plants on the ambient side suffered much more damage from the insects than those in the filtered side. Other researchers have noted the interaction between smog and insects, but further study of this problem is beyond the scope of the project. The visitors were requested to evaluate the differences in insect infestation between the sides of the greenhouse, and some were able to notice the differences. In order to preserve the display, plants that were dying or overly

damaged were discarded and replaced with younger plants. This plant turnover was most frequent during the summer months. The plants replaced most often were carnation, scarlet sage, marigold, coriander, parsley, nicotiana, radish, beans, and corn. The problems of maintaining the display in despite the presence of insects and pathogens are listed on Page 48 and what was done to control them is listed on Page 49.

Something had to be done to provide the visitors who arrived in April, May and June with examples of living plants showing pollution injury symptoms, especially for the parents bringing children to the display. Showing a photograph taken the previous year was not as convincing as a real live plant. The decision was made to include some plants damaged by artificially generated ozone.

During the previous display season, the plant scientists at the Statewide Center Statewide Center for Air Pollution Research, University of California at Riverside, were requested to supply small numbers of plants which had been fumigated in chambers with dosages of ozone high enough to produce a variety of symptoms. These sample plants were popular with the visitors to the Information Center. The decision was made to introduce these artificially damaged plants in large numbers in the greenhouse portion of the display in April, May and June. As is often the case, such a thing is easier said than done. Previous attempts had been made to grow a special set of plants at the Arboretum, transport them to Riverside for exposure in the fumigation chambers, and then back to Arcadia. That process was hard on the plants, and would be too difficult to do with large numbers of plants. It was decided to purchase samples of flowering plants in Riverside, and to grow some of the plants in Riverside. This process was not satisfactory because the design of the study required all the plants to be treated alike except for which side of the greenhouse they were growing. However, there were no facilities at the Arboretum to use as a fumigation chamber. Modifications were made to the greenhouse display to fumigate batches of plants.

Starting in April of 1990, Garret Kats assembled the components of an ozone generator in the Information Center and set up the potting shed as the fumigation chamber. He exposed a large set of plants, which had been grown for this purpose at the Arboretum in the same manner as all the other plants in the display, with levels of ozone known to produce acute injury symptoms to leaves. Pictures of the ozone gener-

ation set up are shown on Page 27. The potting area was closed to the public on three occasions while the plants were being exposed. Plants were exposed to 0.50 ppm ozone for 2 or 4 hours on April 6, April 27, and June 1 and were replaced in the display. These plants were carefully labeled as "laboratory exposures" of pollution. Very visible acute damage symptoms appeared immediately, or developed within a short time. The acute damage was excellent for display purposes: yellow spots and overall reduction in growth were obtained. A picture of what the artificially generated ozone symptoms look like can be seen on Page 59. After June 1, the ambient air pollution levels were high enough to induce symptoms. The early visitors were not disappointed by the absence of living plants showing symptoms.

IMPROVING THE DISPLAY

Improving the display each year in response to visitor comments, or to solve problems, is the method the Arboretum staff used to make the display more attractive to the public. Modifications have been made to the display each year in response to traffic flow problems, problems maintaining the vegetation in a condition which clearly demonstrated air pollution symptoms, and to implement feedback from the visitors.

From the very first, the plants responded dramatically to the difference in air pollution levels in the two sides of the greenhouse, so the project was a successfully constructed and operated as a facility to manage the vegetation portion of the contract. However, this difference was not always apparent to the visitors who had never seen plants growing in clean air and didn't really know what to look for. The modifications all helped to make the exhibit easier to understand and to make the greenhouse more approachable and enjoyable. One visitor commented "I didn't know the public was allowed in here; I thought this facility was for research being conducted by the Arboretum staff." The goal of the modification was to give the exhibit a more inviting appearances without diluting the scientific values of opening a working greenhouse to the public. The purpose of this section of the report is to describe the modifications made to improve the display in the greenhouse and in the Information Center.

Improving the Facilities

During 1987, the greenhouse had the appearance of a typical "working greenhouse" with no outside signs directing visitors to the display. The door to the Information Center was a heavy storm door, painted white and kept closed to preserve the air conditioning, as can be seen on Page 22. It was assumed that the visitors would come first to the Information Center, see the wall posters explaining what air pollution symptoms looked like and how air pollution was formed and monitored, and then they would move on to the greenhouse display itself. The signs identifying the plants were the small, expensive black and silver metal signs so typically found in greenhouses. The display plants were left in the greenhouse the entire season, and removed only if they died. No visual aids were given inside the greenhouse portion of the display to help the visitors identify the various types of air pollution symptoms. What the visitor saw was very dependent on the time of the visit. The Information center contained the wall posters, a few decorative plants, an air quality monitor and a few brochures on the bench top; it functioned more as an attractive entry way than as a resource center. The air quality monitor proved very confusing to the visitors. They had a hard time reading the display panels on the monitoring instruments and could not understand the strip chart readouts. Modifications were undertaken to correct these problems.

Changes were made to most of the signs in the display to make them easier to read. New, large green signs were installed at the edges of the paths directing the visitors to the greenhouse from both sides. The Arboretum made an exception in their sign practice to install these large signs. Pictures of the signs are shown on Page 21.

In 1989, at the end of the display season, enough photographs had been taken to make signs to hang above each type of plant to help the visitor identify the plant damage symptom. These signs reported the name of the plant and showed what it looked like at the beginning of the season and at the end of the season, in the ambient side. The visitor could look up and see the sign above each plant on both sides of the display and could identify the effects of the pollution without constant trips back and forth to examine the plants in the display and the examples on the wall poster in the Information Center. Since very few visitors spent that much time going back and forth, each visitor received better information, even though the signs were duplicative.

The first signs were composed of graphics generated by computer graphics program, printed on typing paper with a laser printer and photocopied onto "cover stock" weight colored paper. Photographs were rubber-cemented to the cover stock, and the entire sign was encased in acetate sheet protectors. Since 40,000 visitors were expected that weekend, the signs were hung with the expectation they would be temporary. They were not expected to survive greenhouse light levels without fading, or survive high humidity levels without curling. No such problems were encountered, so another test was made of the same signs when the exhibit opened in 1990. The intent was laminate them when better pictures were obtained. Despite concerns listed above, these signs survived the entire season without lamination. This simple approach to making signs works, and was continued throughout the display season. Pictures were changed as better ones became available. As a result of these signs, traffic flow was also improved. An example of the sign can be seen on Pages 39, 42 and 43 and a group of signs from 1989 can be seen on Pages 208 to 222.

Another change to the signs were the those signs inside the greenhouse portion of the display which identified the each plant. These small, expensive, metal signs, which are black and silver, were nailed to the bench top (Page 39). Unless the visitor stood over them, they could not be read. No signs were provided for the plants in the bedding area. These signs were all replaced with large paper signs, laminated in plastic. The plant's names were printed on ordinary typing paper using a computer and laser printer. Similar signs were also stapled to grape stakes which were poked in the ground next to the plants in the beds. The size of the sign permitted visitors of all ages to stand on the path and read the name of the plant rather than stepping into the dirt and bending over. While these are not the traditional type of signs seen in greenhouses, they served the purpose of clearly labeling the plant, were easy to make, were inexpensive, and withstood the humidity and any accidental watering they received. They were easy to relocate because they could be thumb tacked rather than nailed to the bench top. Because each season the plants in the display have been changing, each plant can have a name sign as soon as it is put on display. The first signs required a long lead time to purchase and construct. A picture of these new signs can be seen on Page 40.

In 1987 a new see-through door was added to the display, and a large sign was added welcoming the visitors. This

improvement is shown in the picture on Page 22. The glass door did not provide sufficient security, so the original storm door was replaced along with a second thinner door equipped with a see-through plastic. Thus, the needs for security, and temperature control in the Information Center were both met.

Automatic closures were added to the doors in the Greenhouse portion and are effective in maintaining the clean air side of the greenhouse without disturbing public access. In response to the visitors questions, the various portions of the greenhouse's air circulation system were labeled, and in 1990 a poster was added to the Information Center describing how the greenhouse is operated to keep the air free from pollution.

Modifications were made in 1987 and 1988 to the signs on the air quality monitor. It was noted that the public was having difficulties with the word "ambient" so the sign was changed to read "ambient [unfiltered]" air. This problem is a good example of how essential it is to define technical terms that air pollution professionals use so often they are taken for granted. In 1991, the signs above the monitor will be further simplified and re-designed, as there are many questions from the public about the monitoring equipment.

As more and more electronic equipment was added to the greenhouse, additional electrical outlets were needed and the electrical lines had to be upgraded, as shown in the picture on Page 23. The first change was in 1987 to electrical wiring to permit the addition of a big, bright red liquid crystal display panel above the air pollution monitor, as shown on Page 23. The ARB staff in El Monte created this new display to echo the oxidant level being recorded by the ozone monitor recording from the ambient side of the greenhouse. A sign was installed next to the liquid crystal display panel explaining what the numbers meant. This addition solved the problems the visitors were having reading the display on the monitoring equipment. The ink color and the color coding on the strip chart were changed by the ARB El Monte staff because the high humidity in the Information Center was fading the ink on the strip chart. It was hoped that a simple computer-based display could be programmed to show the air quality numbers against a standard background which indicated how close the current readings were to healthy or unhealthy levels. Difficulties were encountered in the purchasing process for the computer. Further difficulties were encountered in programming the computer. No commercially available program can present this data in a graphic format that is simple for the public to see

at a glance. Staff at the ARB have been working to develop such a computer application. Until recently, the computer components and software to accomplish this task have cost thousands of dollars, and the capabilities of the software have been relatively crude.

Electrical outlets were added to permit the installation of the photography studio. The first studio was located next to the door, as shown on Page 25. It was later relocated to the rear of the room, where the pull down cover for the window doubled as a light curtain and a standard background. New electrical outlets were added for the studio and for the automatic slide projector. In 1990, the monitor and the liquid crystal display panel were moved to make room for facilities to photograph the larger plants in the Information Center rather than outside at the end of the display season. A pull down standard background was designed to photograph the larger plants, as shown on Page 26. These changes to the Information Center can be seen on Page 26.

The gravel on the walkway inside the greenhouses creates a dust problem, and needs to be raked smooth to permit the doors to close. The doors must close tightly and the seals have been damaged by the gravel. It may be necessary to replace the doors in 1991. While it is effective in providing a dry walkway, the dust it creates is harmful to the plants in the greenhouse and to the electronic equipment in the Information Center. Plans are being made to replace the gravel with cement pathways.

Improving the Greenhouse Display

Since the display opened, the improvements to the greenhouse portion have consisted of changes in the size and materials of the signs on the individual plants, as discussed above. Modifications have been made in horticultural practices which best display the various types of symptoms. Staff turnover has been stopped, and the plants maintained in a manner that shows the difference between short term responses to "episodes" of pollution and the type of responses which occur after a season's exposure. Many of these details have been discussed in the section on maintaining the display.

In 1990, formal records were kept in a log book. Daily records were kept on visitor attendance, number of questionnaires completed, daily high and low temperatures for outside and in each side of the greenhouse, and the ozone levels at

3:00 p.m. for the ambient and filtered sides. Daily activities such as maintenance on the building, introduction of new plants, and operations of the greenhouse and information center were recorded. Weekly records were kept describing each plant's condition and appearance, including observations on smog damage and pest damage. Monthly reports were written to summarize the month's activities.

For three seasons, an integrated pest management of beneficial insects was attempted as a means of keeping the pests under control. This approach simply does not provide the level of control needed for a museum quality display of air pollution symptoms. Combined with selective applications of pesticides and fungicides, it is possible to keep the insect pests at a level low enough so that their impacts cannot be easily be confused with the impacts air pollution.

Additional individuals each plant displayed have been added to make it possible to photograph the plant response throughout its life cycle. Plants are now removed from the greenhouse after they no longer show vivid symptoms of air pollution, and are replaced with younger more vulnerable plants of the same type. Changes have been made in grooming practices so that the visitors will see the injured, dying, and dead portions of the plants on the ambient side of the greenhouse. The numbers of different kinds of plants have nearly doubled, but the greenhouse looks more spacious than it did in the first year. Careful planning and constant care are responsible for the enhanced appearance of the display.

Improving the Information Center

Photographs on Pages 30-34 show the improvements which have been made in the Information center. The Information Center is shown on Page 30 as it appeared in 1987, before the exhibit was opened. Page 31 and 32 show the wall posters prepared by the ARB staff. Other information available to the visitors were brochures from ARB, and air quality monitors which displayed ozone and oxides of nitrogen readouts on a strip chart. The sections which follow describe the modifications made to the Information Center which transformed it into a resource center on air pollution.

1988 Information Center's Improvements

During 1988, improvements were made to the signs on the monitors. Attempts were made to help the visitors recognize air pollution symptoms by moving pairs of plants showing "the symptom of the day" from the greenhouse into the Information Center.While helpful to the visitors, there was not enough light in the Information Center to keep these plants alive for long, and no provisions had been made to provide special plant sets grown in the display greenhouse for this purpose. Small groups of plants with ozone symptoms were provided by the plant scientists at the Statewide Center for Air Pollution Research, U.C. Riverside; the symptoms were induced by a laboratory exposure to generated ozone. Samples of leaf injury were removed from the plants, and the leaf tissue and appropriate photographs from the previous display season were mounted on poster board and hung in the Information Center, which helped the visitors. The brochures provided by ARB again proved very popular with the visitors but problems were encountered in keeping enough on hand. The visitors enjoyed another new feature of the Information Center, guided tours provided by staff.

Photographic equipment was obtained to document the response of the plants and to assist the visitors in the identification of the symptoms. The photographer selected plants which appeared to best typify the damage being shown by the entire group. No attempt was made to photograph the same plant each session. Details of the photographic set up follow the discussion of the changes and improvements to the displays. Samples of the first type of photographs taken can be seen on Page 24. These photographs were taken outside, on a table borrowed for the occasion from the visitor questionnaire. During this display season, the first photographic studio was set up in the Information Center, on the bench near the main entrance, as seen in the photograph on Page 25. Because of its location, the Information Center was closed to the public during photography sessions.

1989 Information Center's Improvements

A new series of three more wall panels were provided to the Information Center by ARB staff, in a free-standing display. This display emphasized the cost of air pollution to the Agricultural and timber industries, as well as to the State and

National Parks and to the National Forests in California. This display can be seen in the picture on Page 33. The upgrade to the electrical system permitted the installation of a new wall air conditioner and the relocation of the photographic studio to the rear of the Information Center. During the twice a month "photography days," the public had access to the Information Center, and obviously enjoyed watching the shooting sessions. Each session lasted one day, and about one half of the plants in the display were photographed. Twice during the spring of 1989, the display received plants from the scientists at U.C. Riverside. The plants had been artificially exposed to ozone at levels typical of injury-causing episodes of air quality, as monitored by the equipment in the Information Center. They were teamed with non-exposed plants of the same age and species, and explanatory signs and placed on the bench near the main entrance. The addition of these plants ensured that the public who visited at the beginning of April could witness smog damage on a few species of plants, including reduced plant size, leaf spots, fewer flowers and vegetables, and pale color. Tour guides were present again, but with expanded hours, to answer questions and conduct tours. Once again the pamphlets from ARB were very popular, and once again they could not be replaced when supplies ran out.

During the 1988 season, photographs were taken twice a month of selected plants. Two sets of plants of each species were grown for this purpose, labeled as before as "A" and "B" batches. Photographs were taken of both the A and B series [a total of four plants of each species], which took an entire day. The first photographs were black and white prints. Color prints and slides were also taken. After reviewing the photographs, the black and white and color prints were eliminated, because the best results were obtained with slides. The best photographs were enlarged, mounted on backgrounds with appropriate labels and placed on display in the Information Center. Due to the inadequate electrical system, not enough lights could be used to take the photographs and run the air conditioner at the same time until the electrical system was upgraded. Because the Information Center was very dark, new lights were installed by suspending them from the ceiling over the photography studio, as shown in the photograph on Page 26.

In 1989, The standard background for all the photographs was improved. Computer-generated graphics were used to provide standardized labels to assist those who viewed the photographs identify the size, name, date of photo-

graph, and the location of the photograph. The information was mounted on a black piece of tag board which was propped in front of the pots. This practice also saved time, because the pots did not have to be washed for the photograph. Although the black background provided too much contrast, enough photographs were obtained to construct one set of signs to hang over each of the plants in the bench portion of greenhouse. The visitors were able to compare early-season and late-season photographs of the same species to see what changes air pollution exposure could make. A sample photograph showing these improvements is shown on Page 56. The larger plants were not photographed every two weeks because there was no place in the Information Center big enough to do so, and the plants could not be removed from the display since they were planted in the ground. These plants were only photographed at the end of the display season, outside against a wall hung with a long strip of gray paper.

1990 Information Center's Improvements

In 1990, following the relocation of the air quality monitor, and the addition of a pull down backdrop to permit the photographing of large plants resulted in the final version of the standard background, as shown on Page 57. All of the background is the same shade of gray, with black letters generated by computer graphics. The viewer can identify which plant was grown in filtered air, which in smoggy air. The scientific and common name are clearly visible, as is the date of the photograph, the size of the plant, and location of the photograph. The letters A or B identify the plant as one of two batches of plants grown especially for the photographs, so that the same plant could be photographed each session. All the plants in each picture were the same age, and had been started from seed, or were the same size when the photographic sessions started. If distributed to people not visiting the greenhouse, these labels help the viewer understand the picture. The method of placing the larger plants into containers set into the ground made it possible to remove the plants throughout the season for photographs.

These photographs were used to make signs which were hung over each plant on both sides of the greenhouse, as described above, and to make up the first version of a slide show. The slide show was displayed using an automatic slide projector with a built in screen. The signs can be seen in the results section.

The staff consisted of a full-time employee and a part time employee, rather than the 3 to 4 student workers from local colleges. This system was very effective because detailed care could be given to the greenhouse while someone was available to assist the public. On the two days when photographs were taken, the part time student was available to answer questions and give tours.

The layout of the Information Center was adjusted, as shown in the drawing on Page 15 and as can be seen in the photographs on Page 33 and 34. Twenty-five posters were on exhibit. Twelve new posters were designed and introduced in 1990, as indicated by the list on Page 18. Many of the new posters were made in response to questions commonly asked by visitors. For example, the "ozone layer" was often confused with "the ozone" in smog. Many people could not understand the relationship between the two concepts of air pollution inversion layers and global warming, so two posters were made to clarify the difference between layers in the atmosphere and the function/consequences of layers. Changes in the questions and comments indicated the public understood the posters. Another new display was the Air Pollution Poll. A chart of measures which reduce pollution was prepared; visitors were asked to put a check mark by the measures they used to reduce pollution. The addition of ozone generating equipment and the fumigation chamber provided copious amounts of special display material with easily recognized symptoms for visitors who arrived in the spring months. The Information Center layout was also more convenient for short introductory lectures when a group of people arrived to see the display. Additional information, such as booklets, excerpts from books, and recent newspaper or magazine articles were placed in the Information Center. Many visitors used them to learn more about air pollution.

Based on comments from the visitors, the new information brochures prepared by the South Coast Air Quality Management District were greatly appreciated, especially since no brochures were available from ARB. However, the supply of brochures ran out before the smog levels were high enough to produce symptoms. During the final three weeks of the exhibit, the brochure "25 Ways You Can Clean the Air" arrived and was especially welcome by the visitors.

The air quality monitor was maintained weekly by ARB staff from El Monte, and there were no breakdowns of the

monitor as a result. This system for preventative maintenance was very effective and much appreciated.

Improving the Photography

The purpose of the photography sessions was to document symptoms of pollution injury. To be of best use to the academic community and the regulatory community, the photographs needed labels which would identify the date and species, location of the exposure, type of exposure and some indication of the major symptom found in the display.

It took three display seasons to set up the studio and perfect the photography set up to produce the desired results. Examples of the changes made in the photography to help the viewer identify air pollution symptoms can be seen on Pages 50-60. Page 52 shows a close up of air pollution symptoms on celery leaves, but without mounting the photograph on a special background the visitor can not identify the species, age and size of the plant, know what pollutant it had been exposed to or compare this leaflet with one grown in clean air. Page 53 shows the attempt to photograph close ups of leaves from identical pairs of plants, but the visitor has the same problems in interpretation without the preparation of a mounting background. Page 54 shows the first use of a standardized gridded background and pairs of plants in pots shown side by side. However, the background does not give any indication of the date, type and size of species, type of exposure, or the symptoms most evident. This photograph cannot be used as a sign without the addition of a mounting background. Page 55 shows further improvements in the photography set up, the addition of a plastic strip label showing the scientific name, the common name and the date of exposure. It still does not identify the plant grown in the clean air from the plant grown in ambient air. Without a mounting background, the observer cannot see that the plant on the right flowers sooner, has leaf spots, and was grown in smoggy air. Pages 58 through 60 show the photographs of leaves which made up the changing displays in the Information Center; since these photographs were designed to be mounted, they were not taken against the background set up to document growth reductions.

The Results section of this report includes the photographs taken in 1990, and a selection of the best photographs from previous seasons.

Evaluating Visitor Response

The response of the visitors was documented in several fashions. A simple paper and pencil survey was placed in a basket near the exit door. Over 12% of visitors every year completed the survey. The staff giving tours kept an anecdotal log of the responses, and sometimes made changes in the display as soon as possible rather than waiting for an analysis of all the questionnaires.

The publication of articles about the exhibit in widely read, non-scientific publications is a positive response on the part of the viewing public.

In 1989, an outreach program was designed to invite the public to the display. News releases and support materials were sent to 175 regular media contacts. A pitch to TV stations, reporters and writers was made. A brochure was designed and mailed to 1,000 schools, youth groups and other associations inviting them to visit the air pollution display.

The text of the questionnaire is shown on Page 234, and computer generated graphics were made of the numerical responses of the 1990 survey. Similar information is available on the survey from previous years, but not included in the report because the 1990 information is the most current and therefore the most useful. This information is discussed further in the Results Section.

RESULTS

The purpose of this section is to discuss the responses of the vegetation and to the visitors, for each season that the display was open. Pages 61 to 222 illustrate the responses of the vegetation and Pages 223 to 239 illustrate the response of the public to the display. A set of 35 mm. slides of the photographs in this section of the report have been delivered to the staff of the ARB. Because so many of the display plants showed dramatic symptoms of air pollution damage, the public found this display an effective form of public education. The questionnaires revealed that the improvements made each season were effective in making the display easier to understand and in reducing negative comments.

THE 1987 DISPLAY SEASON'S RESULTS

1987 Response of the Vegetation

The symptoms seen are the same syndrome seen each year, and are the ones listed on the table on Page 63. The various plants showed differing combinations of pale leaves, pale spots on the leaves, large spots on the leaves, dying leaves, loss of older leaves, fewer and smaller leaves, flowers and fruit, changes in the length of the stem and in overall form, and shortened life span. These responses occurred each year the exhibit was open ; however their severity, time of onset, and combination varied from plant to plant and from season to season, due to changes in the levels of pollution.

The responses of the plants displayed in 1987 can be seen in the table on Page 65. Twenty six of the plants showed dramatic symptoms of air pollution; 16 did not. The plants that showed the best damage symptoms during the first year are: *Begonia sp.* (Begonias), *Browallea speciosa* (Browallia), *Coleus hybridus* (Coleus), *Dahlia hybrids* (Dahlia), *Daucus carota var. sativus* (Carrot), *Impatiens* (Busy Lizzie), *Petroselinum crispum* (Parsley), *Petunia hybrida* (Petunia), *Phaseolus vulgaris* (Bush Bean), and *Raphanus sativus* (Radish).

Insects and plant pathogens made the recognition of air pollution symptoms difficult, especially on some of the plants like cucumber, so plans were made to attempt an integrated pest control program which did not rely so heavily on pesticides.

Large numbers of requests were made to include rose bushes and orchids. Other requests came in for "*Raphiolepis, Gazania,* Juniper, *Pinus, Zinnia,* Squash, *Camellia,* Hibiscus, *Pittosporum,* Ice Plant, *Podocarpus, Lantana,* Pansy, *Lobularia, Matthiola incana* (Stock), Oleander, Alyssum, Geranium, Sedum." Some of the visitors are familiar enough with plants to request them by their scientific name; some use the common name. Plans were made to improve the greenhouse portion of the display by including as many of the requested plants as possible.

1987 Response of the Visitors

Between April 6 and October 31, 1987, the Air Pollution Greenhouse Exhibit was viewed by 101,717 visitors. Of that number, 1,482 took the time to fill out the questionnaire. The

majority of the responses from the public were positive and they found the display educational. One visitor expressed pleasure that people's " tax monies were being used for a worthwhile project."

Any complaints received were considered opportunities to improve the display. This type of feedback from the visitors formed the basis for recommendations for the following year's display, if the complaint could not be resolved sooner. A brief discussion of the issues that needed improvement follows.

In April, the public did not notice any differences in the plants and they asked what the smog damage was. As the days became smoggier, visitors began to notice the difference for themselves. It took two display seasons to satisfactorily resolve this problem.

From the questionnaire, there seemed to be more interest in the plants than in the monitoring equipment and the wall graphics, so upgrades and improvements to the Information Center were planned for the following display season. Many of the visitors did not understand what was being monitored and found the strip charts on the monitoring equipment difficult to read. The term "ambient air" was particularly troublesome. Several versions of small signs were tried to help the visitors understand the monitors, and the staff from ARB's El Monte office were available as a resource to the Arboretum staff, who also had questions. It was difficult to get the air quality monitored serviced.

The visitors had a hard time comparing the plants in both greenhouses because of the distances involved; this problem was not anticipated and it took several approaches over the next three seasons before a satisfactory solution was discovered and implemented.

Visitors left the doors open, which put stress on the filtering equipment; automatic door closures were planned and installed the following season. Larger signs to direct the visitors to the display were planned because some people commented they had a hard time finding the display.

Many visitors seemed to want "more" of everything--more brochures, more publicity, more information, more plants included, more pictures. It was difficult to keep up with their demands. Not enough brochures were available from ARB. In response to visitor questions, another wall panel

was requested from ARB to explain key facts on "Air Pollution and Human Health." Many requests were received to staff the display so that someone was available to answer questions; this additional staffing was accomplished starting the following display season.

THE 1988 DISPLAY SEASON'S RESULTS

1988 Response of the Vegetation

In response to visitor requests from the previous display season, 23 new plants were introduced into the display and tested for their response to pollution. This list can be seen on Page 67.Thirty three type of plants showed air pollution damage symptoms of the same type as shown the previous season, and as listed on Page 65.

The list of plants which showed injury symptoms in 1988 may be seen on page 68. Twenty nine types of plants showed no significant foliar damage in response to air pollution and should be carefully evaluated for their continued display. Of these plants, the ones requested by the visitors were *Camellia japonica* (Camellia), *Gazania rigens* (Gazania), *Delosperma 'Alba'* (Ice Plant), *Juniperus chinensis 'Pfitzerana'* (Juniper), *Matthiola incana* (Stock), *Pelargonium hortorum* (Common Geranium), *Pinus canariensis* (Canary Island Pine), *Pittosporum tobira* (Tobira), *Podocarpus macrophyllum* (Yew Pine), *Raphiolepis indica* (India Hawthorn,) *Viola wittrokiana* (Pansy), *Zinnia elegans* (Zinnia), and three varieties of roses: *Cecile Brunner, Honest Abe cv. Aaron,* and *Beverly Hills cv. Delmatore.* Even if the plants requested by the visitors do not turn out to be reliable and excellent examples of air pollution injury, the results can be used by visitors who want to know what CAN be planted that is not likely to have air pollution damage.

Problems encountered with equipment breakdowns were solved, and the automatic door closures helped reduce the stress on the equipment without disturbing traffic flow.

Once again an integrated pest management program of beneficial insects was attempted to control the insect pests, but was not successful because the vendor could not deliver the promised insects before the infestation was completely out of control. Spraying was necessary to preserve the vegetation in the display in a condition that showed the air pollution symptoms. It took most of the season to get the pests totally

controlled and the display suffered as a result.

Additional staff was hired in response to visitor request from the previous season, to serve as tour guides. The public appreciated the presence of the college student tour guides. The students selected were all students of the plant sciences, but turnover was high and they required much closer supervision in horticultural practices than was expected.

Plans were made to include additional plants requested by the visitors.

1988 Response of the Visitors

The project was viewed by 9,108 visitors from April 4, 1988 to October 31, 1988. Of that number, 684 visitors filled out the questionnaire. Due to the extreme heat, visitor count to the Arboretum was unusually low all summer, and school tours were greatly reduced due to cuts in school budgets. The visiting public was very pleased to be greeted by the tour guides. Articles about the exhibit appeared in the July issue of *SUNSET* Magazine. The full text of the article, which appeared in the Southern California edition, can be seen on Page 226. An article about the exhibit also appeared in the San Gabriel Times, and can be seen on Page 227. *LANDSCAPE & IRRIGATION* covered the display in February, 1988; a copy of the article can be seen on Pages 231 to 237. A small segment on the Arboretum was aired by NBC news.

Improvements were made to the Information Center and the Greenhouse display, in response to visitor comments the previous season. Photographs were taken of 29 types of plants, and the best of the color prints were on display in the Information Center. These photographs were helpful in telling the public what to look for when they entered the greenhouse portion of the display.

Better signs were successful in guiding visitors to the display, and the new signs on the air quality monitor prevented a repeat of the difficulties experienced the previous season. A second air quality monitor indicated to the visitors that there was no air pollution present in the clean air side of the greenhouse. Another electrical outlet was installed and the liquid crystal display hung above the monitoring equipment . These improvements made the ozone readings much easier to understand, and are shown in the picture on Page 23.

The new panel on the impacts of air pollution on human health was prepared by the ARB staff and helped answer visitor questions.

The visitors had difficulty seeing smog damage, particularly in the spring. It was recommended that next display season, during the early months of the display plants should be artificially exposed to ozone to demonstrate typical smog damage symptoms.

Once again, the ARB brochures were very popular and the supply ran out quickly and could not be re-filled.

The 1989 DISPLAY SEASON'S RESULTS

1989 Response of the Vegetation

Eighteen new plants were included in the display or possible inclusion in the display. Their names and responses are listed in the table on Page 70. The most dramatic adverse effects were shown by *Gazania rigids, Celosia plumeria, Centaurea cineraria*, and *Salvia splendens.* Five more hybrid teas and two miniature rose bushes were incorporated in response to the continuing overwhelming number of requests for more roses. Thirty-eight of the plants in the 1989 display showed air pollution damage, as listed on Page 71. Eleven plants showed no significant foliar damage; some of these plants should be re-evaluated for growth reduction comparisons because it was difficult to get plants of the same size from commercial vendors at the start of the display season. The best plants for permanent inclusion in the display are *Apium graveolens v. dulce, Begonia sp., Celosia plumeria, Petunia hybrida, and Phaseolus vulgaris* because the differences can be seen from one side of the exhibit to other, through the glass dividing wall. Of the plants which were new to the display, the most dramatic responses were shown by *Ageratum houstonianum* (Floss Flower), *Celosia plumeria* (Cockscomb), *Centaurea cineraria* (Dusty Miller), *Gazania rigids* (Gazania), *Lobularia meritima* (Sweet alyssum), *Magnolia grandiflora* (Southern Magnolia), *Prunus caroliniana* (Carolina laurel), some of the roses, *Ulmus parvifolia* (Chinese Evergreen Elm), and *Zinnia elegans,* (Zinnia).

The new signs, which contained pictures of plants with smog damage, were hung above the plants in the greenhouse

portion of the display. They helped the visitors see the differences in the plants which showed damage.

Again, an integrated pest control management program was attempted, this year by using ladybugs. Pest infestations were major problems in both sides of the greenhouse, with aphids, snails, whiteflies, gray mold, spider mites and powdery mildew and ants adversely affecting the plants at various times. Without extreme care, the cure is harder on display plants than the pests. Widespread damage occurred to the plants from applications of Malathion, pointing out the sensitivity of plants growing in a greenhouse may be greater than those outdoor. Due to the heat and pesticides, broccoli and cauliflower were discarded and restarted. A new problem occurred: a rodent ate the broccoli and corn. Wire mesh was installed over all the lower vents. Safer's Insecticidal Soap was applied to control aphids every 7 to 10 days starting in August; Pentac and Mavrik were used in June and August; metaldehyde pellets were used to quell snails. So many problems were experienced with the following plants that serious consideration should be given to replacing them with more pest free varieties: *Brassica oleracea* (both broccoli and cauliflower), *Capsicum annuum* (Pepper); *Cucumis sativis* (Cucumber), *Cucurbita sp.* (Squash), and *Solanum melongena* (Eggplant).

1989 Response of the Visitors

Between April 1, 1989 and October 31, 1989, 15,651 visitors saw the display. The month with the highest attendance way May, with 5,777 visitors. Twelve per cent of the visitors, 1,853 people, filled out the questionnaire. The *Los Angeles Times* also covered the exhibit on September 30; a copy of the article can be found on Page 230. A local paper, *The Highlander*, also covered the exhibit on May 31; the text can be found on Page 228. In August, KCBS TV news covered plants and pollution, and mentioned the greenhouse in this segment.

Judging from the responses to the questionnaires, the 1989 visitors had a thought-provoking and informative experience. Because the questionnaires are not always dated, there was no way to tell if the people who could not see the difference arrived early in the spring. The people who thought the plants looked better in the smoggy greenhouse were probably viewing plants that were flowering sooner in response to the

stress. If they had taken the guided tour, the latter fact would have been pointed out to them.

When asked if they found the exhibit informative 96% said "yes" in April and May; 98% said "yes" in June and July; 97% said "yes"in August and September; and 95% said "yes" in October. In April and May, 59% found the plants the most interesting part of the exhibit; 58%, in June and July; and 61%, in August and September. When asked if the information was presented in a way that was easy to understand, 93% said "yes" in April and May; 89% said "yes" in June and July; 93% said "yes" in August and September; and 95% said "yes" in October. When asked if they knew about air pollution causing damage to vegetation before seeing the exhibit, 78% said "yes" in April and May; 76% said "yes" in June and July; and 93% said "yes" in September. When asked if they believed individual actions could help reduce air pollution, 83% said "yes" in April and May; 80% said "yes" in June and July; 85% said "yes" in August and September.

To evaluate which type of display plant was preferred, the visitors were asked to identify the plant which most interested them. Twenty-one per cent were most interested in vegetables; 13%, the roses; 5%, the petunias; 4%, the cockscomb; 4%, "flowering plants"; 3%, the trees; 2%,cyclamen; and 2%, the fruits, herbs, and shrubs. One per cent liked the begonias, zinnias, carnations, Impatiens, coleus, marigolds, and grasses. Under 1% picked as their favorite plant the geraniums, snapdragons, dahlias, lobelia, grapes, dusty millers, or floss flowers. When asked what they would like to see added to the exhibit, 1% wanted orchids and cacti. A few people wanted native plants or drought tolerant plants, ferns, pine trees, strawberries, azaleas and gardenias.

Twenty per cent of the respondents took the time to write comments. Many people wrote simple "thank you" in the questionnaire. Others took the time to write longer responses, such as "This exhibit ought to be mandatory." There were very few negative comments. Thirteen people wrote they could not tell the difference, or that the plants looked better in the smoggy air. Twenty four people complained about the insect infestation. Twenty eight people, or 1%, took the time to ask for more information on the greenhouse itself or on how to do something for the plants and vegetation in California.

The modifications to the facilities and displays suggested by the visitor responses were implemented. Four student

workers staffed the exhibit, with turnover stopping in May. Tours were given, and attention was called to the artificially exposed plants from U.C. Riverside which were received twice during the summer. For the first three weeks of their stay in the Information Center, these plants were an effective representation of smog damage. Many of the visitors could not take advantage of this display because they were only available three of the seven months the exhibit was open. Positive responses were given to the other improvements in the display.

The three panel free-standing display explaining the extend and cost of air pollution damage to California's agricultural and forest industries was popular with the visitors, and the see-through door made the greenhouse entrance more inviting. Moving the photography studio to the rear of the Information Center permitted the public to observe the sessions and prevented the closing of the Information Center for many hours.

Once again the chronic shortage of handout material was a problem in the Information Center. Due to a mix-up with the Los Angeles supplier, the South Coast Air Quality Management District was not able to replenish their brochures; no brochures were available from the ARB.

Mechanical problems occurred with the monitoring equipment and the swamp coolers on the unfiltered side of the greenhouse; it was difficult to get the air quality monitors repaired in May and September.

An evaluation of the display's effectiveness was made at the end of the season and several improvements were recommended for the following year. The most important one concerned the improvements needed in the photography. During the last week of the display enough photographs were available to mount above the plants to give visitors a chance to see what the same plants had looked like much earlier in the summer. Written descriptions such as "Leaf spot or " color change" showed the visitors what to look for. This approach was especially successful, and should be continued as new photographs become available.

Recommendations were made for implementation in 1990 to enhance the photography, such as changing the black title board to the same gray color as the background board, to reduce "hot spots" in some of the photographs. The filtered air and smoggy air identification cards should be attached to

the title board in the foreground, rather than the background, to provide a more uniform focus. The dates of photographs should be determined in advance to give lead time to print up the plant names and photography dates in the same print run. Prior to the opening of the exhibit, sets of plant identification cards should be prepared in advance to meet the needs of the photographers.

More light is recommended for the Information Center. When visitors come in from the bright lighting of the Arboretum grounds, the Information Center seems too dim by comparison, and the visitors tend to walk quickly through without taking time to read the wall posters and see the air quality monitors. Any display vegetation placed in the Information Center will also benefit from enhanced light.

THE 1990 DISPLAY SEASON'S RESULTS

Response of the Vegetation

Seventeen new "test" plants were included in the display, as shown in the list on Page 73. Two were not able to survive in the greenhouse, and it is recommended that French tarragon and avocado be re-evaluated for inclusion in the display. Page 74 indicates which of the 81 plants in the 1990 display season showed symptoms of air pollution damage: 49 plants displayed one or more symptoms of air pollution. As shown in the table on Page 75, 10 of the display plants exhibited no significant foliar damage. The tables on page 76 to 84 indicate which plants had what type of symptom or symptoms. Photographs of the vegetation follow, from Page 85 to 208.

The reader's attention is called to the series of photographs of three of the display plants. The growth and development of pairs of plants is traced in a series of photographs from the time the plant was placed in the exhibit to the end of the display season. The series of photographs on Page 190 to 195 shows how the growth of *Asplenium bulbifernum* (Mother Fern) is impacted almost immediately and continues to show growth reduction in the ambient side of the greenhouse. Each of the 10 photographs show the reduction, which was accompanied by a color change which may be seen on the picture of a section of frond shown on Page 58B.

The series of 10 photographs on Page 196 to 201 show how air pollution can reduce growth in *Citrus sinensis*, (Orange). In this plant, the impact was not very evident until the growth spurt of the plant in the filtered side, between the 7/18/90 and 8/1/90 photography session. The plant in the filtered air continued to outgrow the plant in the unfiltered air and ended up about twice as big as the one in the ambient air. This plant indicates that there can be a critical period of time during which the symptom will clearly show.

The 10 picture series on *Primula sp.* (Primrose), on Pages 202 to 207 tells a third story about the expression of the symptom called "growth suppression." It was very difficult to get Primrose to live very long in the ambient air; this plant was started over three times, and visitors saw plants labeled A, B, and C. The photographs in the series show the "B" plants because this group of plants lived the longest, from the 4/11/90 photography session to the 8/15/90 session. Plants in the ambient air did not grow as big, have as many flowers, and the blooms did not last as long. Primrose is a very popular spring bedding plant; for families with limited budgets for landscaping, the impact of air pollution on primrose can make it an expensive investment.

All the plants varied in their sensitivity to air pollution. As a group, the vegetables were among the most sensitive, as were the herbs. They were the plants most interesting to the visitors, according to the previous year's survey. The plants which showed the least damage were the drought-tolerant varieties such as Dusty Miller, Gazania, Juniper, Lavender, Indian Hawthorn, and Eucalyptus. The larger plants also tended to be less sensitive to air pollution. This resistance could be due to the fact they grow more slowly than the annual plants, or they may not be in the most sensitive stage of their life cycle. It may take longer for the impact to be evident. It is beyond the current scope of the display to answer these questions. The flowering plants varied in their sensitivity: the most damaged were Petunia, Nicotiana, Cyclamen, Primrose and Viola. Floss Flower, Snapdragon, Impatiens, and Scarlet Sage were moderately damaged. All varieties of geranium (the Martha Washington, Lemon Balm and Common Geranium) showed the least amount of damage. Both ferns grown (Mother Fern and Common Tansy), showed a dramatic response to air pollution.

Air Pollution had a dramatic impact on the root systems of plants, which is an effect not previously demonstrated for

visitors. The next display season will attempt to document this reduction in the size of the root ball. When the plants were being removed from the containers, the most affected were the Coleus, Dusty Miller and Niagra Grape. The California Red Onion Plant had larger bulbs when grown in clean air.

In addition to the direct damage that ambient levels of pollution have on plants, lowered resistance to pests is a severe problem in the smoggy side of the greenhouse. After an application of pesticides to eradicate the pests, the plants in the ambient side of the greenhouse took longer to recover from any pesticide damage. Beans, Celery, Floss Flower and Impatiens were especially sensitive to damage from pesticides. The table on Page 48 identifies the type of plants that had problems with insects, molds, and heat stress. The table on Page 49 indicates what pesticides and fungicides were used to eradicate the pests. Even when label instructions were followed, the plants growing in the unfiltered side of the greenhouse suffered some damage from the pesticide itself. Pesticides were used more often than in previous years, which greatly improved the appearance of the display. A wide variety of pesticides were used, including those which permitted spot treatments of plants.

Leaving the large plants in containers, and setting them into in larger containers buried in the ground permitted the removal of the display plants throughout the season for photographs. In previous years, plants were placed directly into the soil and could only be photographed at the end of the season.

The tours continued to be popular with the visitors, and the signs placed in the greenhouse improved the experience for the visitors. Photographs from the previous season were hung over the plants before the display opened. Visitors could see what the response of the plant had been in the spring and fall of the previous year. The display area had a more uniform appearance and the signs were legible from across the greenhouse. The signs which identified the type of damage to look for were one of the most effective ways to guide the visitor through the display. Some visitors prefer to guide themselves, and then come to the tour guide with questions.

The fumigation chamber set up in the potting shed provided the opportunity to open the display with copious amounts of plant material demonstrating air pollution damage,

and selected examples were also placed in the Information Center.

Staffing made a difference in the appearance of the display. One very dedicated person, working part time, provided consistent plant care on a regular basis throughout the display season. Plants were quickly removed from the display and replaced with those which would better display the symptoms identified by the signs. The other full time staff member conducted the tours, managed the record keeping, planning, timely purchase of supplies, arranging repairs, the photography preparations, and all the other administrative chores required to keep the exhibit open and running smoothly. It is our experience that one person cannot manage this entire project, and that some personnel have to be in the greenhouse every day.

Further improvements can still be made in the selection and care of the plants. All plants selected for display must be the same size and more appropriately sized for this greenhouse. No matter how frequently requested by the public, trees are not good candidates for display in a greenhouse because often the symptoms do not become apparent in one season. If trees and vines are used, dwarf varieties should be chosen. Plants which are prone to pests should not be included, and a strict schedule for pesticide application should be set and followed. June, July, August and September are months requiring spraying. A wider variety of pest controls, such as long term ant poison or sticky fly traps should be tried. Plants that have become severely infested are better discarded than saved, even if the photography sessions are curtailed for that individual. Plants exposed to high levels of ozone show the effect for only two weeks, and the damaged parts tend to drop off quickly and must be removed. If ozone fumigations are used, the best schedule is every two weeks in April and May, and once mid-way through June. After this time, the ambient pollution levels are high enough to impact the plants.

The methods for displaying the plants are well enough known at this time so that more attention can reliably be placed on linking the amount of air pollution and the onset of pollution symptoms. Air quality information is needed to accomplish this task. Until now, air quality is not formally recorded; however the monitor runs reliably 24 hours each day. Modifications would need to be made in the operation of the exhibit to link air quality readings with the onset and severity

of air pollution injury symptoms and to establish a relationship between the amount of growth loss over a season with the total number of hours of pollution to which the plant was exposed. This information is likely to cause a problem to the visitors unless the complex relationships usually expressed in scientific terms can be adequately portrayed.

The design of the greenhouse and the manner in which it is run makes the clean air side of the greenhouse a good "control" in experimental design. The filtered side ozone levels were kept below 0.010 ppm, and usually near 0.000 ppm., the lowest level that the air quality monitor can reliably detect. Records kept of ozone readings during the 1990 display season indicate that the months of April and May were relatively smog free, with only a few days exceeding 0.050 ppm ozone inside the ambient greenhouse. The months of June, July and August were the most smoggy, with weeks of readings over 0.100 ppm. The months of September and October had progressively lower levels of ozone. Because the ARB staff from El Monte provided weekly service to the air quality monitor, the air quality data being gathered is of research-project quality. Since levels of ozone exceeding 0.05 ppm are enough to cause visible damage to sensitive plants, the April through October season is still a good time frame for the exhibit to prove that existing levels of smog cause visible amounts of air pollution to commonly grown ornamental and garden plants.

One aspect that is pointed out by the tour guides on days when ozone levels read above 0.07 ppm is the "ozone" smell in the ambient side of the greenhouse. When they moved to the ambient air side of the greenhouse, the tour guides asked everyone to "take a good sniff" and report what they smelled. Many people were visibly shocked that they could readily sense the difference in the air quality after only a few moments in the filtered side.

1990 Response of the Visitors

Between April 11 to October 31, 1990, approximately 14,000 people visited the greenhouse display. May was the busiest month, with attendance at 2,800. June was the least attended month, with 1,500 visitors. School groups on field trips were common in April and May. An average of 10 groups of 15-20 students visited per week day. These groups were given a brief lecture in the Information Center followed by the tour of the exhibit. June, July and August brought many day camp children to the display. These visitors were shown plants

with damage and asked to point out similar damage on other plants and were encouraged to ask questions about the display. The reaction of the visitors to the exhibit was monitored by talking individually to the visitors and by the brief questionnaire that many people took the time to answer.

Pages 215 to 230 contain graphs and charts which display the responses to the questionnaires. The chart on Page 230 summarizes the responses for the entire season. As in previous years, approximately 12% of the visitors answered questionnaires. Nearly all found the display informative throughout the season (98%). Asked if they found it easy to understand, only 5% answered "no." They didn't say they failed to understand it, only that it took some work. The visitors continued to rate the plants themselves as the most interesting aspect of the exhibit. No matter how good, a picture is just not as interesting to them as a living plant. However, the graphics did get a better rating than in previous years. Most people already knew that air pollution can damage plants (76%), but they paid to attend the exhibit anyway. Only a few would admit they did not know specifically what the effects were.

Fifty nine per cent of the visitors claim they can recognize air pollution symptoms similar to what they saw in the exhibit near their home or in their yards. The chart on Page 227 indicates that 65% of the visitors recognize air pollution symptoms on trees, and 56% see them on flowers. Most are identifying the symptoms as yellow or brown leaves, and as reduced growth. The latter is interesting, because reduced growth is something best seen when an individual plant is compared directly with one grown in identical environmental conditions, except for air quality. This response is an interesting one which could be further investigated next season.

The tour guide recorded spontaneous comments, in addition to the written comments. Visitors often exclaimed to their companions with words to the effect that "This looks just like my..." or "NOW I know what those spots...." One Hundred and eighty seven people wrote written comments that said the exhibit was "Great, thank you." Thirty two wanted more publicity, 19 wanted more information, 3 volunteered to "help", 3 singled out the staff as very helpful. Only 11 said they saw no difference in the plants, compared to 13 the previous

year. Only 2 didn't like the insects, compared to 24 the year before. At least one of the visitors indicated an intention to write their elected public officials a thank you letter for funding the exhibit. The changes to the horticultural practices and the additions of the ozone fumigated plants were effective improvements, based on the visitor responses.

Seventy eight per cent of the visitors believed that their individual actions could improve air quality, as seen in the chart on Page 218. The Air Pollution Poll results are shown on Page 218. One hundred and eighty five visitors admitted they car pooled; 53 had reduced their driving; 52 mentioned walking or biking; 37 claimed to have had a very recent car tune up;, 27 were recycling; 24 were avoiding the purchase and use of chemicals which contribute to the "greenhouse effect" or "adversely impact the ozone layer."; 28 claimed to have stopped smoking. Only 75 bravely admitted they had done absolutely nothing to improve air quality.

The visitors were asked to recommend plants for the display. The chart on Page 219 shows that 32 visitors wanted the display to include the types of trees which grown in the forests, rather than "lawn trees". Thirty one requests were made for still more roses; 30 requests were for edible plants; 17 for fruits; 17 for vegetables; 15 for grasses (omitted this year) and ground covers; and 13 for orchids.

The goal of asking questions focused on urging people to think about air pollution as "my problem" and not just "those other guys' problem" was met, as evidenced by the response of the visitors. The responses of the visitors are being used to improve the display next season.

Press coverage this season was the article which appeared in January issue of the magazine *The Plain Truth.* This article is interesting because the layout of the article copies the layout of the greenhouse: the Clean air side of the greenhouse and four of the plants are shown on the right page of the spread, and the ambient side of the greenhouse and the damage to the same four plants, in mirror order, are shown on the left page of the spread. Page 248 is a copy of the article.

The relocation of the air quality monitor, the changes to the background for the photography set up, and the changes in the method of displaying the larger plants enabled pictures to be taken of every plant in the display, as compared to the numbers of signs which were made from pictures the previous

year (seen on Pages 208-212). All three elements were needed to make major improvements in the photographic record.

There were no breakdowns of the monitor as a result of the weekly service calls from ARB. Additional posters were added which clarified some of the major issues bothering the visitors. However, considerable difficulties were encountered in repairing damaged air ducts. It took 2 months to repair some of the tubes, because supplies had to be ordered. If the breakdown had occurred at the height of the smog season in the clean air side of the greenhouse, the entire exhibit could have been ruined. A supply should be kept in the greenhouse in anticipation of a probable breakdown. The anticipation of mechanical problems leads to the identification of vendors and repair people to call when something breaks. This information was not available to the new staff managing the display, and unnecessary delays were the result.

An automatic slide projector purchased the previous year could be used because there was finally a sufficient number of good slides to construct a slide show. It was one of the more popular displays in the Information Center. Similar information was conveyed with wall charts and posters, but the slide show was something that was brightly lighted, colorful and it presented a moving image.

Problems still exist with the display. The following discussion lists the problems and a suggested solution.

Visitors still claim difficulties finding the greenhouse. Not all the Arboretum staff can guide visitors to the Air Pollution Greenhouse. At the beginning of the season, a special invitation should be issued to the entire Arboretum staff to tour the greenhouse, and any new employees and volunteers, especially those driving the tram or answering the phone should be able to point out the Air Pollution Greenhouse. The growth along the paths to the exhibit can be trimmed back to make the greenhouse more visible from the major walkways.

If the summer temperatures match those experienced last summer, the greenhouse will be too hot on the ambient side. When the temperatures exceed 90^0F, the plants experience heat stress. Shade should be provided. A coat of white lime would reduce the temperature in the greenhouse without reducing the level of light required by the plants.

The quality of the photographs is still variable. Despite using the same camera, the same film, the same background, the same positioning of equipment, and the same vendor to develop the film, some of the pictures are very "yellow" rather than gray. After exhaustive tests, it seems that the problems are related to under exposure. More lights might be used, but the electrical power is already taxed to its limits. The lighting causes the Information Center to become very hot. A roof line heat exhaust fan or a bigger air conditioning unit might be required, but that will further tax the electrical circuits. One simple procedure that can help is to clean the air conditioner filter more frequently, and generally reduce the amount of dust in the Information Center. Daily sweeping will be required. Pouring cement walkways instead of the gravel walkways in the greenhouse will greatly reduce the dust levels.

Dust in the Information Center presents a problem to the electronic equipment. The slide projectors and the air monitoring equipment are also very dusty, despite frequent cleaning. A protective box or container should be made to keep the dust off the equipment. Although sound is not used now, the slide projector has the capacity to include a sound track with the slide show. This part of the equipment is very vulnerable to dust.

A small computer has been purchased, along with the equipment needed to capture the signal from the air quality monitoring equipment. Although there is no commercially available software to display the air quality at the non-technical level required for this exhibit, ARB staff has been developing a graphic display for the computer. Under present dust levels, the computer would be at risk, unless protected with some sort of cabinet. Recently, faster computer components at lower prices have become available, making an attractive computer display feasible. Such a display would require a second computer with a fast processor chip and large amounts of storage space to store images of the plants and animation software will be needed to make an attractive display. Additional hardware will be required to permit the computer to simultaneously monitor the air quality and be "interruptible" enough to respond to queries put to it by visitors touching the monitor screen. Most of the visitors do not linger a long time over any single element of the displays, so the programming would have to be flexible enough to give meaningful information about air quality and permit those who wish to spend more time at the computer to do so. Just as the presence of a living plant is more appealing than the best

photograph, and the presence of a flashing slide show is more appealing than posters and wall charts, the presence of a computer display with a touch screen "controls" will certainly improve the quality of the display. As with the photographs, the information could be made available to the general public in a format similar to the "demonstration disks" prepared by computer software vendors.

At least half of thee visitors were children. New posters and displays in the Information Center should be designed for them. At present, some of the wall posters are too complicated for them. Brief visits to supply houses for teachers indicate that very little supplemental class room material is available on plants. The posters introduced this season were handwritten. Now that the visitors seem to understand them, they should be re-done with enhanced graphics.

Over 100 requests came in from all over the country for more information about the display and its results. A small booklet describing the exhibit and summarizing the results is needed. The possibility of providing slide sets at cost to educational institutions should be investigated.

Again during the 1990 display season, no brochures were available from the ARB, and the brochures from the South Coast Air Quality Management District were not available until late in the season. A supply of 10,000 of each type of brochure is needed at the start of the season, particularly the brochure on the 25 actions individuals can take to reduce air pollution.