DRAFT FINAL REPORT

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

Contract No. S-C93011

Prepared for

The South Coast Air Quality Management District

by the

California Arboretum Foundation

Los Angeles County Arboretum

301 North Baldwin Avenue

Arcadia, CA 91007

June 21, 1993

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ABSTRACT

The Air Pollution Greenhouse display was operated during the 1992 Smog Season and is currently open for the 1993 Smog Season. 1993 marks the seventh year of the display. This report summarizes the scope of the work, methods used and results of the operation of the display from April 1992 to May 1993.

During the months of April 1992 through October 1992, approximately 17,000 people visited the display. The response of the visitors to the display was overwhelmingly positive. Outreach programs during the year included lectures, tours of the greenhouse,

and media coverage. Information about the results of the effects of smog on ornamental and home garden plants was disseminated to various organizations and individuals. 65 different species of plants were grown in the 1992 Smog Season. Of the 65 species, 44 had indeterminate smog sensitivities. 30 out of the group of 44 developed symptoms. 12 of these plants had medium to high levels of damage.

During the 1993 season a selection of native California plants are being grown. Native California plants were requested by visitors and also represent a category of plant that has not been widely studied for air pollution sensitivities. 60 different species are being grown and although it is too early to determine results, three of the California plants have developed high levels of injury symptoms. The educational and outreach programs in 1993 are being developed like during 1992. An Independent Student Projects Program has been initiated with Arcadia High School and 12 students are currently doing research on various air pollution issues from the effects of air pollution on plants, to making educational posters and developing solutions to local air pollution problems.

INTRODUCTION

The Air Pollution Greenhouse is an on going project which was initiated and designed by the California Air Resources Board and the Los Angeles County Arboretum in 1987. Funding for the Air Pollution Greenhouse during the 1992 and 1993 seasons was provided by the South Coast Air Quality Management District, Southern California Edison and the California Air Resources Board. Technical support, plant donations and contributions in kind were provided by the Los Angeles County Arboretum, United States Department of Agriculture Forest Service, University of California Riverside, Los Angeles County Fire Department Forestry Division, Theodore Payne Native Plant Foundation, and the Tree of Life Nursery.

The Air Pollution Greenhouse serves the purpose of increasing and promoting public awareness of the effects of air pollution on plants. Vegetation in the metropolitan Los Angeles region represents a major investment to wide segments of our society. Homeowners, developers, and cities spend millions on landscaping and maintenance of plants. Furthermore, as some plants, particularly trees, grow larger they increase in value. Air pollution has been know to have a wide range of detrimental effects on plants such as reduction in growth rate and leaf damage. Most of the plants grown in the Air Pollution Greenhouse are those that are commonly grown in yards and gardens in the Los Angeles region. By focusing on the impacts of smog on plants, the public is made more aware the costs of air pollution damage and how it has a negative effect on the

quality of their own neighborhoods. The hope is that pubic interest in programs to improve air quality will increase and that people will be more supportive of these programs.

Information on the responses of forest and agricultural vegetation has been well documented over the past 20 years. In southern California, Jeffrey Pines in the San Bernadino Mountains suffer from chlorosis of the needles and premature death. Farmers in the San Joaquin Valley lose profit from reduced crop yield. In both situations smog, primarily ozone, was the cause of this damage. Unlike forest trees and agricultural crops, home garden and ornamental plants have not been widely studied for air pollution sensitivities. The importance of these types of plants cannot be overlooked since they make up the majority of vegetation in the Los Angeles metropolitan region. The Air Pollution Greenhouse provides a controlled environment to study ambient air damage on a large number of ornamental plants. In the past 7 years, over 200 varieties of plants have been grown in the Air Pollution Greenhouse. Design of the Air Pollution Greenhouse is unique. The greenhouse portion is split in half by a glass wall. One side of the greenhouse receives air which has been filtered to remove major air pollutants and the other receives ambient air. Identical sets of plants are grown in each half of the greenhouse and all growth conditions are kept the same except for the air quality. Information on each of the plants' response to ambient air is documented by written observations on the plants' overall appearance. Photographs of plants throughout the smoggy season are take on a semimonthly or monthly basis. The information obtained on ornamental plant responses to air pollution has served as a resource for homeowners, gardeners, landscapers and city planners who are looking for plants which are tolerant to smog and maintain a healthy and beautiful appearance.

An information room is adjacent to the greenhouse. The information room contains educational materials such as posters, sample plants showing smog damage, reference books on previous plants grown in the greenhouse, and ozone monitors. Posters explain how smog is formed, what are the leading causes of smog, how smog affects plants, how smog affects humans, and what individuals can do to improve air quality. Posters also explain how the Air Pollution Greenhouse is designed and how plants are maintained. Ozone monitors serve to inform people about how smog levels are measured. The monitors serve to measure and record ozone levels in each side of the greenhouse. Handouts and brochures are given to people to take home with them. Handouts are provided from the South Coast Air Quality Management District.

Since 1987, approximately 180,000 people have visited the Air Pollution Greenhouse. A large percentage of the visitors have been students on school trips. But the visitors have represented all segments of society. An optional questionnaire is used to monitor public response to the display and its value in education. Conversations with visitors were also used as indicators of strong and weak points of the display. The pubic response to the Air Pollution Greenhouse has been overwhelmingly positive. Most people were aware that air pollution might have an effect on plants, but did not know how or to what extent. They appreciated how the information was understandable and many terms they had heard before were explained to them. Many felt that there should be more places where information on general aspects of air pollution effects could be found. People were also unaware of the specific effects of air pollution on their health.

Outreach programs are developed for The Air Pollution Greenhouse so that more people than on site visitors can benefit from the information. Outreach programs include tours for school teachers and community groups so that they can inform other people

about the display; lectures and talks to horticultural societies and school organizations; written responses to individuals requesting specific information. Programs which involve local high school students in research projects were designed and implemented. Media coverage has included magazine and newspaper articles, radio and television coverage.

DESCRIPTION OF THE AIR POLLUTION GREENHOUSE

Description of the Greenhouse Facility

The Air Pollution Greenhouse was constructed in 1987 at the Los Angeles County Arboretum in Arcadia, California. It is located near the entrance of the Arboretum in the southern edge of the South African section. When visitors arrive at the Arboretum, they receive a map of the garden which shows the location of the Air Pollution Greenhouse display (att.1). One major pathway and two smaller pathways lead to the display and large signs along the pathway point visitors in the correct direction. Improvements to the area around the display include the trimming of large trees that block the visibility of the greenhouse, landscaping around the area which is currently in progress and larger signs showing directions. Guided tram tours through the Arboretum describe the Air Pollution Greenhouse and point out it's location.

The greenhouse portion of the display is 33 feet by 35 feet and is divided in half lengthwise by a glass wall. Each half has bench area for smaller potted plants and a ground level area for larger plants. A pathway runs between the benches and ground level area through which visitors can walk. The greenhouse is designed such that the halves are in mirror image orientation so that visitors can look through the glass partition and see the matching plant grown in the other side. A potting area and information room

connect to the greenhouse (att.2). The greenhouse was designed to grow plants in environmental conditions that match closely in temperature, humidity and light intensity to the outside environment. To maintain temperatures between 55 F at night and 85 F during the day, the greenhouse is equipped with "swamp coolers" which are regulated by an automatic thermostat. Orientation of the greenhouse is such that plants are exposed to the same average light intensity over the day. Clean air quality is maintained in one half by using pleated dust filters and activated charcoal filters over the coolers which circulate air from outside of the greenhouses to the inside. The ambient side of the greenhouse has dust filters over the coolers.

Description of the Information Center

The Air Pollution Greenhouse display is open during the "Smog Season" which is the months of April through October. The display hours are 9:00 am to 4:30 pm, seven days a week. The main entrance to the Air Pollution Greenhouse display is through the information center. The information room has wall space for posters, table space for display plants and reference books and an area for the ozone monitors (att.3). The information center contains posters on a variety of air pollution issues, but focuses on air pollution damage to plants. More than 20 posters explain the basics in understanding smog, how it effects plants and humans, and the purpose of the greenhouse display (att.4). The ozone monitors are housed in a clear plexiglass case that allows visitors to see the numerical readings and correlate it to regional air quality standards. There are two ozone monitors used in the display and are provided by the Air Resources Board. ARB technicians calibrate and do routine maintenance inspections on the monitors and chart recorder. One ozone monitor measures ozone concentrations in the filtered side of the greenhouse and the other measures concentrations in the ambient side. Both

measurements are recorded by a chart recorder. Chart records are kept to show daily highs and lows and overall exposures levels. Other materials in the information room include sample plants of one showing smog damage and the other grown in clean air. People can inspect the two plants side by side and the damage symptoms are clearly explained to them. A binder of photographs of plants grown in previous years is kept as a reference and lists of smog tolerant and sensitive plants are provided for people interested in finding plants that grow well in smog. Informational handouts for visitors to take home with them were provided by the South Coast Air Quality Management District (att.4). There is a staff person or volunteer available during the morning on weekdays and during the afternoons on weekends. These are the peak visitor hours of the display. Staff and volunteers answer questions for visitors and give tours to school groups.

OUTREACH PROGRAMS

Successful outreach programs that have been implemented in the past were continued. Outreach programs have the major goal of providing information about the Air Pollution Greenhouse to large groups of people either by soliciting tours of the greenhouse for large organizations or going to organizations and giving lectures. Outreach programs include the use of brochures about the greenhouse. Another way of spreading information about the Air Pollution Greenhouse is by media exposure usually in newspapers, magazines, television and radio. All of these methods were pursued during 1992 and 1993.

List of outreach activities from July 1992 to May 1993 in chronological order.

1. Tour of Air Pollution Greenhouse for 40 students in the University of California, Cooperative Extension Master Gardeners program on July 31, 1992.

2. Television coverage on KTLA-Channel 5 Morning News. Two interviews with Gloria Mao in Air Pollution Greenhouse. Aired on August 26, 1992.

3. Television coverage on KCET-Channel 28 broadcast of "Ozone, the Hole Story." Interview with Gloria Mao about Air Pollution Greenhouse and smog damage. Aired on August 25, 1992. Repeated on other PBS stations nationally.

4. Radio coverage on KNX-CBS News Radio. Interview with Gloria Mao aired August 26, 1992. It was a repeat of interview from summer 1991.

5. Presentation to 70 Southern California Edison employees about display on September 7, 1992.

6. Meeting with Arcadia School District and Pasadena School District teachers held on September 21, 1992. Presentation about the display and brochure with information on arranging school trips given to both school districts.

7. Interview with Whittier Daily News on October 15, 1992. Article not yet in print.

8. Tour for 90 Northridge University Biology Department students on October 12, 1992.

9. Tour for 30 members of the Los Angeles Conservation Corps on October 14, 1992.

10. Lecture at the University of California Cooperative Extension Garden Conference on October 17, 1992. 40 people in attendance.

11. Presentation about environmental research given to 4 classes at the Rowland Heights School District for their "Career Awareness Week" on March 5, 1993.

12. Lecture on smog tolerant plants given at the Southern California Historical Society on April 4, 1993. About 100 people in attendance.

13. Interview for Southern California Gardener Magazine given on May 26, 1993. Article print date is July 1993.

Two new outreach programs were implemented during fall of 1992 to be in activity during 1993. The new programs were in response to conversations with local area public school teachers. Teachers were looking for ways for students to get more involved experience with working on and solving environmental problems. Within the limits of Arboretum staff time and budget monies, a program with Arcadia High School was initiated. 12 students would be selected to do independent research projects in which they would study a specific air pollution issue. The students would have to choose specific topic to study, write a proposal, do the research work and deliver a paper or product at the end of the project. Some of the finished products would be posters and information for the information room of the Air Pollution Greenhouse. Some of the projects involved working on specific plants in the greenhouse by measuring and

recording growth and air pollution symptoms. Arboretum staff would provide students reference books, supplies and materials as well as guidance.

The second outreach program was to provide university students with space in the greenhouse to do research work. Two students, Lydia Yoshida from California State University, Los Angeles and Roy Wiersma from California Polytechnic University, Pamona are currently studying plants for their susceptibility to smog damage. Students found out about the Air Pollution Greenhouse from University of California Riverside, Statewide Air Pollution Research Center (SWAPRC). SWAPRC is not currently operating functioning air chambers and to our knowledge, the Air Pollution Greenhouse is the only operative controlled filtered air chamber in the region.

OBJECTIVES

The Air Pollution Greenhouse display has several objectives:

-The Air Pollution Greenhouse serves as a research facility for the screening of a variety of plant for their sensitivities to air pollution damage. Plants grown in the greenhouse must have interest to the public. Primarily home garden and ornamental plants are selected for the greenhouse. Public requests for native California plants and local area forest trees were responded to by including several of these types of plants. Information on plant responses to air pollution is compiled for reference and is provided to the public on request.

-The Air Pollution Greenhouse serves as an educational facility. In order to increase public awareness of air pollution problems, it is designed to be understandable

and accessible to the general pubic. The Arboretum attracts people form all over the southern California region, charges a low admission fee and is open every day of the week from 9:00 am to 5:00 pm which makes it possible for people to who work regular hours to visit the display. Other means of making the information more accessible is by outreach programs such as lectures and media coverage.

-The Air Pollution Greenhouse serves as a supplement to school science classrooms. It can be used as a location in which to do independent research work and to find references and resource materials.

METHODS OF MAINTAINING THE AIR POLLUTION GREENHOUSE

Maintaining the Greenhouse Environment

The greenhouse was designed to keep the inside air at the same temperature and relative humidity as the outside air. This design factor was important in that plants grow differently in a topical greenhouse environment which is used to enhance the growth rate of plants. Evaporative coolers, often called "swamp coolers," were selected which could maintain the greenhouses between a low of 55 F at night and a high of 85 F during the day. On days where outside temperatures are over 100 F, maximum temperatures in the greenhouses are 92 F which does not typically cause damage to plants. If temperatures were allowed to match that of outside of outside on extremely hot days, the greenhouse would be too hot for visitors to walk through. Each side has two evaporative cooler units which are equipped with .5 horsepower motors and 115 V water pumps. Each cooler is rated at 5500 CFM. All coolers are surrounded by a dust filter to keep outside dust from being blown into the greenhouses.

Air circulation keeps the greenhouse under positive pressure so that even with doors to the greenhouse being opened, air is flowing constantly outward. Circulation and humidity are controlled by convection tubing along the top of the greenhouse and fans at each end of the tubing keep the air moving. This system keeps a rapid rate of air flow throughout the entire greenhouse. Air inside the greenhouses are expelled through 4 oz. barometric shutters located near the top of the greenhouse.

The filtered side of the greenhouse is equipped with activated charbon filters. The filters are installed outside of the coolers so that air must first pass through the filters before it moves through the coolers. The carbon filters are protected with pleated dust filters. All carbon filers and dust filters are replaced once a year. In the past, the carbon filters were effectively removing ozone after one year, but are replaced each year in March before the beginning of smoggy season.

The ozone monitors and a strip chart recorder are provided by the Air Resources Board. The ARB calibrated and did monthly service inspections on all equipment during the months of April 1992 through October 1992 and in March 1993 up to the current date. One monitor is used to measure concentrations of ozone in the filtered side. The monitor insures that the carbon filters are functioning properly by removing ozone to levels around 0.000 ppm. On days where ambient smog levels reach above 0.200 ppm, filtered side levels can reach up to 0.010 ppm which is considered negligible amounts. The other monitor measures ozone levels in the ambient side of the greenhouse. Ozone levels for both sides of the greenhouse are recorded on the strip chart recorder which graphs the levels 24 hours a day. Monitors measure average ozone levels per minute and the recorder correlates with these measurements.

Maintaining the Greenhouse Plants

Approximately 60 varieties of plants can be grown at any one time in the greenhouse which allows for a sampling of three to eight plants of each variety. For larger plants, only one plant in each side is grown. One third of the plants are ones that have shown clear smog symptoms and are popular with visitors. These plants are called the core group of plants. About one third of the plants are ones that have been grown in the greenhouse in previous smog seasons, but it was unclear was to whether symptoms were due to smog or other damaging factors like insects or disease. In some cases these plants were grown again because they did not survive for long in the greenhouse. The rest of the plant are species which have not been grown previously in the greenhouse.

Plants are selected on criteria such as popularity of plant, ability to grow in a greenhouse environment, relative resistance to insects and diseases, simple growth requirements, simple maintenance requirements. About two thirds of the plants in the 1992 smog season were home garden plant. One third were native California plants and forest trees. Visitors had in the past requested that more of these types of plants be grown. Availability of the plants often dictated final plant selection. Plants were obtained by growing from seeds, from the Arboretum nursery, from local commercial nurseries, and from donations from specialized nurseries such as the Los Angeles County Fire Department Forestry Division which maintains a tree nursery.

Plants are installed in the greenhouse during the month of April. Plant care involves standard horticultural practices. All maintenance and growth conditions are kept identical for both sides of the greenhouse. Plants are watered daily or as necessary.

Fertilizer (20-20-20) was applied once every two weeks. Grooming is kept to a minimum where dead leaves, spent flowers and broken branches are removed. If trimming occurs, the same quantities are taken from plants on both sides. The major maintenance work on plants involves eliminating insects pests and fungus. Pests which appeared during the 1992 season include aphids, spider mites, whitefly, scale. Pests can cause damage of plants that might be confused for smog damage. Therefore, pests were removed as soon as they were detected. A policy of using non-toxic pesticides such as Safer Soap was attempted. This was not successful. Safer Soap eliminated pests for only 2 consecutive days after which pests would return in the same or greater quantities. Stronger pesticides are more effective in eliminating pests. Unfortunately some plants are damaged by the stronger chemicals and take a number of days to recover.

As plants died or became too damaged to serve as display plants they were removed. The plants which are seasonal or annuals were not replaced. Other plants which could continue growing through the summer were replaced.

METHODS OF RECORDING PLANT RESPONSE TO SMOG

During the 1992 smoggy season, the plants which had not been grown previously in the display were photographed every two weeks beginning May 18 and ending October. One plant from the filtered side was photographed next to the same plant grown in the ambient side. The same pair of plants was photographed throughout the season.

During the 1993 smoggy season, new plants were photographed once a month beginning May 24 and will end the last week in August. The schedule was changed due to the change in plant appearance not altering that much in a two week interval.

Written observations on the appearance of plants were kept weekly on all plants new to the display. Such observations include the following

1. Leaf color
2. Relative plant size
3. Rate of growth
4. Quality and quantity of flowers
5. Presence of dropped fruit and leaves
6. Production of fruit
7. Viability of plant
8. Relative root size (if the plant was sacrificed at the end of the season)
9. Plant resistance to pests and diseases
10. Recovery of the plant after pesticide application
11. The length of time each plant was used in the exhibit
12. Time to onset of symptoms of smog damage

METHODS OF RECORDING VISITOR RESPONSE TO DISPLAY

Three methods are used to determine the value of the display to the visitors. The major method is by using optional questionnaires to poll visitor interest in the display, educational worth, the most informative aspects of the display, ways people were trying to improve air quality, and general comments (att.). Questionnaires are provided to the public during the months of April through October

Another method is by informal conversation with visitors. This is valuable in obtaining detailed information about what they learned and which topics they would like to see more information. This is the only way to determine if posters are effective, whether the information is complete and if they still have major questions which the information center has not addressed.

The last method is by having a sign in sheet in the information room where people write their names (school group if applicable), address and comments. The sign in sheet is most valuable for determining from what regions people are coming from. The goal is to attract visitors from all over the South Coast Air Basin.

RESULTS OF PLANT RESPONSE

Results of Plant Response during 1992 Smog Season

A total of 65 different species of plants were grown in the 1992 smoggy season of April through October. 12 species had been grown in the greenhouse during previous smog seasons, but for various reasons, no rating was determined for the plants. These plants were being re-screened. 32 species were new to the Air Pollution Greenhouse display. 21 species were standard plants which are called the core group because they are easy to maintain and show a variety of smog damage symptoms. Observations on plant appearance was taken for all plants except for the core group. Photographs were taken of the plants new to the display.

A list of all the plants grown and the information regarding symptoms and relative sensitivities to smog damage is in att. . The final list of plants grown in the display varies from the proposed list of plants for several reasons. The proposed list of plants was based on looking through nursery catalogs. Availability often changes each year. Many of the plants were not propagated during the winter for spring planting. Some of the plants looked to be in poor health or condition. Overall, the plants were either not available or unsuitable for display.

Of the 44 species observed, 12 showed no visible smog damage during the 1992 smoggy season. Only one of these, the Rock Rose (Cistus salvifolius), was a herbaceous, non-woody plant. The majority were woody shrubs and trees. Although it could be that woody plants are overall more tolerant to smog than herbaceous plants, it is more likely that the short term of observation of only one smog season is too short of a time to measure any smog response. Ozone levels during the 1992 season were comparatively low compared to previous years. It is likely that the levels were too low to cause visible acute damage on these plants. Also, since woody plants and trees have longer life spans than herbaceous plants, the long term damage to these plants is more important to study than one smog season's effects.

There were 18 plants that showed low levels of smog damage. Low levels of damage are usually shown by a reduced growth rate or size of plant, but showing no other negative effects or yellow leaves which die and are replaced by healthy new leaves. Nearly half the plants showed this type of combination of symptoms. To a gardener or even horticulturist, this would be considered normal growth since the plants are quite healthy in overall appearance. Many of the plants know to be drought tolerant fell into the low level category. 13 of the 18 were drought tolerant. These are the California

Poppy, Blue Fescue, Ice Plant, Mondo Grass, Moss Rose, Bird of Paradise, Aloe, Lamb's Ears, Rosemary, Bottle Brush, Jerusalem Sage, Australian Flame Pea, Chalk Dudleya. Three other low level damaged plants, Strawberry, Bromelia, Wandering Jew grow in well drained soil and have relatively low water requirements. Two of the low level damage plants, Meadow Rue and Mandevilla need high amounts of water compared to most. The water requirements of these plants makes sense in that air pollutants enter leaves through stomates. Drought tolerant plants either have a lower concentration of stomates, or keep stomates closed during the heat of the day to conserve water.

Nine of the 44 species showed medium levels of smog damage. Foxglove, Gerbera Daisy, English Ivy, Orchid, Spurge, Yellow Monkey Flower, Engelmann Oak, California White Oak, Hollyleaf Cherry. A wide range of damage symptoms appeared on these plants. Most showed a reduced growth rate and yellow leaves. Smaller leaves or fewer leaves was common also. In some cases, other differences occurred such as a smaller root ball or shortened life span. These plants show a wide range of horticultural needs and growth environments.

High levels of damage occurred to three plants: Beard-Tongue, Sage (mulleri), Trigger Plant. Plants that developed more that two symptoms and symptoms which were very obvious, were placed in this category. Sages in general are relatively tolerant to smog. It seems that smog resistance is not characteristic common among all the species of sages. Beard-Tongue and Trigger Plant are low in water requirements. No generalization can be made about these three plants except that one would have predicted them all to be smog tolerant. It is possible that the ideal horticultural care was not given to these three plants, but filtered specimens looked very healthy compared to the ambient specimens.

Overall, the California native plants grew poorly in the greenhouse. They were prone to fungus and insects more so than the ornamental and trees. Since all of the natives were obtained from the same nursery, it could be that unhealthy plants were used in the study. Two of the plants died after a few months in the greenhouse. Others looked unhealthy and never grew to a fully "symptom free" appearance.

Results of Plant Response during 1993 Smog Season, April through May

There are 60 species of plants being grown in the Air Pollution Greenhouse display for the 1993 smog season. The plant list and results of the growth during the months of April through May is in att.. The results are not final and will change as the ozone levels increase during the summer. Of the 60 species, 40 are new to the display. The most sensitive plants to date are the Tree Mallow, California Buckwheat, and Sycamore. They are all native California plants. The information seems to show that several of the native plant species are sensitive to smog. As a group, native plants are not highly studied. Given that some of the wildlife regions in California are under stress due to development and pollution, the effects of smog on native plants should be studied.

OZONE LEVELS

Ozone levels during 1992 Smog Season

Ozone monitors in the Air Pollution Greenhouse display are used to determine ozone exposure of plants in the ambient side of the greenhouse. Another ozone monitor measured levels in the filtered side of the greenhouse. The ozone levels in the filtered side never went above 0.010 ppm during the 1992 Smog Season.

For the months of April through October, the number of days which exceeded the state standard for ozone levels (over 0.09 ppm, for over one hour) are listed:

April- 19 days

May- 15 days

June- 17 days

July- 24 days

August- 23 days

September- 17 days

October- 10 days

The highest ozone reading was 0.275 ppm on July 25. July, August and September had the highest overall levels where many of the days were above 0.150 ppm. In April, May and June there were only 9 days above 0.150 ppm.

<u>Ozone levels during 1993 Smog Season, April through May</u>

For the months of April through May, the number of days which exceeded the state standard for ozone levels (over 0.09 ppm, for over one hour) are listed.

April- 5 days

May- 8 days

The highest ozone level during April and May was on. Only two days exceed .150 ppm in May.

RESULTS OF VISITOR RESPONSE TO DISPLAY

Results of Visitor Response to Display during 1992 Smog Season

Approximately 17,000 people visited the Air Pollution Greenhouse during the 1992 Season. The months of greatest number of attendance were May and June. Many schools came for visits during these months and about 70% of the visitors are with a school group. During May and June on weekdays, an average of 150 students tour through the display. August and October are the months with lowest attendance. August was a hot month and attendance at the Arboretum was low. The number of visitors to the Air Pollution Greenhouse display is dependent on the number of people visiting the Arboretum. There were occasions where a visitor came to the Arboretum specifically to see the Air Pollution Greenhouse display.

A total of 653 questionnaires were completed in 1992. In answer to the first question of "Did you find the exhibit informative?" 98% responded yes. 92% found the exhibit easy to understand. The plant displays were the most interesting to 46% of the visitors compared to the graphics (14%) and monitors (10%). Many people (30%) noted that they found all of the exhibits interesting. These results are similar to the results in previous seasons. 75% of the visitors answered that they knew that air pollution could injure plants. Some wrote on the questionnaire that they did not know the specific symptoms. 62% had seen air pollution injury on plants near their home. The purpose of asking this question was to make people think in terms of how air pollution is affected them personally. The questions on what they did to reduce air pollution is another way of getting visitors to think about their actions as affecting the environment. When asked if they thought individual actions can help improve air quality, 81% answered yes.

The list of plants most interesting to the pubic has not changed much over the years. Roses, vegetables in general and trees are some of the most popular requests. When asked for their favorite plant in the greenhouse display, there was a broad spectrum of answers, but it was usually a plant with a lot of flowers and showy display. Exotic plants and native California plants are also favorites and requested often.

The comments were almost all positive. Many of the people requested that there be a way that more people could visit the display or the display could be taken to schools. Questionnaires show that people are enjoying the display, that it is thought provoking and informative. The level of information is suitable for the general public and the posters with pictures are understandable to junior high level students.

The sign in sheet of names and addresses of visitors shows that people are visiting from all parts of Los Angeles County and there are also visitors from every county surrounding. From Orange County there were visitors from Anaheim, Orange, Irvine, Tustin, Huntington Beach, Laguna Beach. From Riverside and San Bernadino there were visitors from Riverside, Ontario, Big Bear. Most of the visitors were from the San Gabriel Valley area, but there was a large percentage of school groups from the Los Angeles School District. The entire South Coast Air Basin was represented in sign in sheet.

Interviews with visitors showed that people were very enthusiastic about learning about air pollution. One of the basic gaps in understanding was what smog is composed of. Many did not know that ozone was the major component in smog. Many did not understand about the difference between the Greenhouse Effect and air pollution. Posters in the Information room address these issues.

Results of Visitor Response to Display during 1993 Smog Season, April through May

In April there were approximately 1,600 visitors to the display. There were approximately 3,900 visitors. In May there were about 150 school students each weekday. 211 questionnaires have been completed. The results look similar to the 1992 season. Sign in sheets and interview are still being used as methods of monitoring visitor response to the display.

CONCLUSIONS

Summary of data from plants grown in Air Pollution Greenhouse Display - 1992 Season

Information on each plant is listed in the following order:

-Common name/Scientific name

-(P) if it has corresponding photograph

-Dates of period grown in greenhouse

-List of smog damage symptoms

-Rating of relative sensitivities to smog damage: (0) no visible smog damage, (1) one symptom and low level of damage, (2) two symptoms and medium level of damage, (3) more than two symptoms and high level of damage

-Comments on special horticultural problems

<u>Plants grown in previous seasons which were re-screened to determine response</u>

1. Foxglove/Digitalis purpurea

April 16, 1992 to June 15, 1992

yellow leaves, reduced size, shortened life span

rates 2

-Annual spring plant that expires in greenhouse in mid-June which is before peak smog levels; unless propagated later in season around late May, it has limited use in the display; very susceptible to aphids and spider mites.

2. California Poppy/Escholzia california

April 16, 1992 to June 15, 1992

pale leaves

rates 1

-Flowers in mid-May and expires around mid-June; cannot keep the plant in display through the summer months.

3. Blue Fescue/Festuca ovina glauca

April 16, 1992 to October 31, 1992

reduced size

rates 1

-Exceptionally easy to care for plant-resistant to insects and diseases. Late onset of symptoms which first appeared in August 1992.

4. Gerbera daisy/Gerbera jamesonii

April 16, 1992 to July 30, 1992

yellow leaves, smaller leaves

rates 2

-Susceptible to fungus and aphids

5. English Ivy/Hedera helix

April 16, 1992 to October, 31, 1992

reduced growth rate and size, pale leaves, less dense root spread

rates 2

-Onset of symptoms occurs late in the smoggy season around mid August.

6. Ice Plant/Mesembryanthemum rosa

(P)

April 16, 1992 to October 31, 1992

reduced growth rate

rates 1

7. Mondo grass/Ophiopogon japonicus

April 16, 1992 to October 31, 1992

reduced growth rate, yellow tips on blades, weak root system

rates 2

8. Orchid/Cymbidium x suva 'Royal Velvet'

April 16, 1992 to October 31, 1992

pale leaves, reduced growth rate

rates 2

-Exceptionally easy plant to maintain in greenhouse. Flowers are very showing which is popular with visitors. Flower production is equivalent filtered and ambient plants and that often is misleading to visitors who do not notice leaf quality as being the indicator of health.

9. Sweet Olive/Osmanthus fragrans

April 16, 1992 to October 31, 1992

no visible damage

rates 0

-Susceptible to aphids and sooty mildew, recovers well from pesticides

10. Moss Rose/Portulaca grandiflora

April 16, 1992 to October 31, 1992

reduced size

rates 1

11. Strawberry/Rosa fragaria

April 16, 1992 to July 30, 1992

smaller leaves

rates 1

-Does not grow well in pots, leaves are prone to fungus.

12. Bird of Paradise/Strelitzia reginae
April 1, 1992 to October 31, 1992
reduced size
rates 1

Plants which are new to display

-Ornamental and Home Garden Plants

1. Aloe/Aloe saponaria
(P)
April 16, 1992 to October 31, 1992
reduced size
rates 1

2. Spurge/Euphorbia rigida
(P)
April 1, 1992 to October 31, 1992
thin stems, small leaves, small root ball
rates 2
-Goes dormant in late summer and leaves tend to turn yellow

3. Lamb's Ears/Stachys lanta

(P)

April 1, 1992 to October 31, 1992

high rate of leaf death

rates 1

-Susceptible to aphids and ants, "Safer Soap" causes leaves to yellow

4. Beard-Tongue/Penstemon sp.

(P)

April 1, 1992 to September 22, 1992

brown leaves, shorter life span, smaller root ball

rates 3

-Difficult plant to maintain in pot because spreading growth; does not grow well in greenhouse (high humidity), susceptible to aphids and spider mites.

5. Rosemary/Rosemarinus officinalis

(P)

April 1, 1992 to October 1992

reduced growth rate

rates 1

6. Sage/Salvia mulleri

(P)

April 16, 1992 to October 1992

fewer leaves, fewer flowers, reduced growth rate, shortened life span

rates 3

-Difficult plant to grow in pot due to spreading growth pattern, ambient side more susceptible to spider mite damage

7. Bromelia/Bromelia sp.

(P)

April 16, 1992 to October 31, 1992

smaller leaves, fewer leaves

rates 1

8. Wandering Jew/Tradescantia fluminensis

(P)

April 1, 1992 to October 31, 1992

reduced growth rate

rates 1

9. Bottle Brush/Callistemon pachyphyllus var viridis

(P)

April 16, 1992 to July 30, 1992

reduced growth rate

rates 1

10. Rock Rose/Cistus salvifolius

(P)

April 1, 1992 to July 30, 1992

no visible damage

rates 0

-Susceptible to aphids, gnats and fungus

11. Mandevilla/Dipladenia 'Red Ridinghood'

(P)

May 27, 1992 to July 30, 1992

reduced growth rate

rates 1

-Susceptible to aphids, sooty mildew, ants; did not keep long in the display due to insect damage

12. Jerusalem Sage/Phlomis fruticos

(P)

May 27, 1992 to July 15, 1992

reduced growth rate

rates 1

-Greenhouse too humid which caused fungus and leaf rot; did not keep long in the display

13. Australian Flame Pea/Chorizema cordatum

(P)

April 1, 1992 to July 30, 1992

yellow leaves

rates 1

14. Trigger Plant/Stylidium adratum

(P)

April 1, 1992 to July 30, 1992

yellow leaves, reduced growth, fewer flowers

rates 3

-Native California Plants

15. Toyon/Heteromeles artbutifloia

June 16, 1992 to October 31, 1992

no visible damage

rates 0

-Susceptible to sooty mildew and ants

16. Meadow Rue/Thalictrum polycarpum

June 16, 1992 to July 15, 1992

reduced growth rate

rates 1

-Unhealthy plants, filtered side was not very green and had yellow leaves; plant needs to be screened again.

17. Chalk Dudley/Dudleya pulverulenta

June 16, 1992 to October 1992

reduced growth rate

rates 1

18. Manzanita/Arctostaphylos 'Howard McMinn'

June 16, 1992 to October 1992

no visible damage

rates 0

-Unhealthy plants, two out of three in filtered side died within one month after installation in greenhouse.

19. Purple Monkey Flower/Mimulus hybrid purple

June 16, 1992 to July 30, 1992

undetermined

-Unhealthy plants, most died within two months of growth in greenhouse

20. Yellow Monkey Flower/Mimulus cardinalis 'Yellow'

June 16, 1992 to August 15, 1992

yellow leaves, reduced growth rate

rates 2

-Unhealthy plants, all died after three months of growth in greenhouse

21. California Fuschia/Zauschneria 'Catalinae'

June 16, 1992 to July 15, 1992

undetermined

-Unhealthy plants, died of fungus and root rot

-Forest Trees

22. Engelmann Oak/Quercus engelmanni

May 20, 1992 to October 1992

fewer leaves, reduced growth rate

rates 2

-Trees will be kept in greenhouse through the winter and measured in May 1993

23. Digger Pine/Pinus sabiniana

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through the winter and measured in May 1993

24. California Live Oak/Quercus agrifolia

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

25. California White Oak/Quercus lobata

May 20, 1992 to October 1992

fewer leaves, high rate of leaf death

rates 2

-Under heat and stress, plant drops leaves. Greenhouse was too warm for trees. Plants will be kept in greenhouse through winter and measured in May 1993

26. Knobcone Pine/Pinus attenuatta

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

27. Coulter Pine/Pinus coulteri

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

28. Bigcone Douglas Fir/Pseudotsuga macrocarpa

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

29. Coast Douglas Fir/Pseudotsuga menziesii

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

30. Italian Stone Pine/Pinus pinea

May 20, 1992 to October 1993

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

31. Hollyleaf Cherry/Prunus ilicifolia

May 20, 1992 to October 1992

fewer leaves, reduced rate of growth

rates 2

-Trees will be kept in greenhouse through winter and measured in May 1993

32. Incense Cedar/Libocedrus decunraus

May 20, 1992 to October 1992

no visible damage

rates 0

-Trees will be kept in greenhouse through winter and measured in May 1993

-Core Group of Plants - used to demonstrate smog damage symptoms

1. Onion/Allium cepa

2. Chives/Allium schoenoprasum

3. Celery/Apium graveolens 'Utah 52-70R'

4. Mother Fern/Asplenium bulbiferum

5. Cockscomb/Celosia plumeria

6. Dusty Miller/Centaurea cineraria 'Silver Queen'

7. Orange/Citrus

8. Coleus/Coleus hybrid

9. Cyclamen/Cyclamen hybrid

10. Carrot/Daucus carota

11. Impatiens/Impatiens hybrid

12. Sweet Alyssum/Lobularia maritim

13. Tomato/Lycopersicon lycopersicum 'Ace 55VF'

14. Flowering Tobacco/Nicotiana alata

15 Parsley/Petroselium crispum

16. Petunia/petunia hybird

17. Bush Bean/Phaseolus vulgaris 'Derby'

18. Primrose/Primula

19. Radish/Raphanus sativus 'Plum Purple'

20. Rose/Rosa

21. Pansy/Viola

Summary of data from plants grown in Air Pollution Greenhouse Display - 1993 Season from April to June

Information on each plant is listed in the following order:

-Common name/Scientific name

-(P) if has corresponding photograph

-Dates of period grown in greenhouse

-List of smog damage symptoms

-Rating of relative sensitivities to smog damage: 0 through 3

-comments on special horticultural problems

Plants which are new to display

-Ornamental and Home Garden Plants

1. Scotch Moss/Sagina sublulata
   April 4, 1993
   reduced growth rate
   rates 1

2. Hydrangea/Hydrangea 'variegata'
   April 4, 1993
   reduced growth rate
   rates 1

3. Dragon Tree/Dracena draco
   April 4, 1993
   no visible damage
   rates 0

4. Banana/Musa acuminata 'Zebrina'
   April 4, 1993
   reduced growth rate
   rates 1

5. Orchid Cactus/Epiphyllum 'Schlumbergikia Bridgesii'
   April 4, 1993

no visible damage

rates 0

6. Sago Palm/Cycas cycadaceae

April 4, 1993

no visible damage

rates 0

7. Plumaria/Plumeria

April 4, 1993

fewer leaves

rates 1

8. Sycamore/Platanus racemosa

March 31, 1993

reduced growth rate, smaller leaves

rates 2

9. Cape Honeysuckle/Tecomaria capensis

April 4, 1993

fewer leaves, yellow leaves

rates 2

10. Copper Leaf/Acalypha wilkesiana

April 4, 1993

reduced growth rate, smaller leaves

rates 2

11. Purple Velvet Plant/Gynura aurantiac

April 4, 1993

reduced growth rate, yellow leaves

rates 2

12. Philodendron/Philodendron

April 4, 1993

smaller leaves

rates 1

13. Sea Onion/Urginea maritima

April 4, 1993

reduced growth rate

rates 1

-Forest Trees- same trees that were grown during 1992 season

1. Engelmann Oak/Quercus engelmanni

May 20, 1992

reduced growth rate, fewer leaves

rates 2

2. Digger Pine/Pinus sabiniana

May 20, 1992 to March 31, 1993

All trees died from wooly aphid

3. California White Oak/Quercus agrifolia

May 20, 1992 to March 31, 1993

All trees infested with whitefly

4. Knobcone Pine/Pinus attenuata

May 20, 1992

reduced growth

rates 1

5. Coulter Pine/Pinus coulteri

May 20, 1992 to March 31, 1993

All trees died from wooly aphid

6. Bigcone Douglas Fir/Pseudotsuga macrocarpa

May 20, 1992

no visible damage

rates 0

7. Coast Douglas Fir/Pseudotsuga menziesii

May 20, 1992

no visible damage

rates 0

8. Italian Stone Pine/Pinus pinea

May 20, 1992 to March 31, 1993

All trees died of wooly aphid

9. Hollyleaf Cherry/Prunus ilicifolia

May 20, 1992

reduced growth rate, fewer leaves

rates 2

10. Incense Cedar/Libocedrus decurrens

May 20, 1992

no visible damage

rates 0

11. California White Oak/Quercus lobata

May 20, 1992

reduced growth rate, leaf death

rates 2

-Native California Plants

1. Red Columbine/Aquilegia formosa var truncata

March 31, 1993

pale leaves

rates 1

2. Bush Anemone/ Carpenteria californica

March 31, 1993

reduced growth rate, smaller leaves

rates 2

3. Ceanothus/Ceanothus 'Dark Star'

March 31, 1993

reduced growth

rates 1

4. Tecate Cypress/Cupressus forbesii

March 31, 1993

reduced growth rate

rates 1

5. Beach Aster/Erigeron glaucus 'Arthur Menzies'

March 31, 1993

fewer leaves, reduced growth rate

rates 2

6. California Buckwheat/Eriogonum fasciculatum

March 31, 1993

reduced growth rate, pale leaves

rates 2

7. Hybrid Coral Bells/Heuchera hybrids

March 31, 1993

reduced growth rate, pale leaves

rates 2

8. Tree Mallow/Lavatera assurgentiflora

March 31, 1993

reduced growth rate, pale leaves, smaller leaves

rates 3

9. Mexican Lobelia Bush/Lobelia laxiflora

March 31, 1993

reduced growth rate

rates 1

10. Nevin's Mahonia/Mahonia nevinii

March 31, 1993

no visible damage

rates 0

11. San Diego Willowy Mint/Monardella linoides ssp Viminea

March 31, 1993

no visible damage

rates 0

12. Scarlet Bugler/Penstemon centranthifolius

March 31, 1993

reduced growth rate

rates 1

13. California Wild Rose/Rosa californica

March 31, 1993

suffered from damage to "Sunspray" an oil based pesticide; plant is recovering from damage

14. Black Willow/Salix goodgingii

March 31, 1993

no visible damage

rates 0

15. Creeping Sage/Salvia sonomensis

March 31, 1993

reduced growth rate

rates 1

16. Desert Grape/Vitis girdiana

March 31, 1993

no visible damage

rates 0

Core Group of Plants

1. Cockscomb/Celosia 'plumosa'
2. Impatiens/Impatiens 'New Zealand'
3. Petunia/Petuna 'Orchid Daddy'
4. Primrose/Primula acaulis
5. Bush Bean/Phaseolus 'Ramona'
6. Celery/Appium graveolens var. dulce
7. Carrot/Daucus carota var. sativus
8. Tomato/Lycopersicon lycopersicum
9. Parsley/Petroselinum crispum
10. Rose/Rosa 'Mikado'
11. Orange/Citrus 'Kara Mandarin Orange'
12. Sword Fern/Nephrolepsis exaltata
13. Dusty Miller/Centaurea cineria

14. Coleus/Coleus hybridus
15. Mondo Grass/Ophiopogon japonicus
16. Azalea/Azalea So. Indica 'Pride of Dorking'
17. Daylily/Hymeracallis'Russian Rhapsody'
18. Cymbidium/Cymbidium x suva 'Royal Velvet'
19. California Fan Palm/Washingtonia filifera
20. Ice Plant/Drosanthemum 'floribundum'