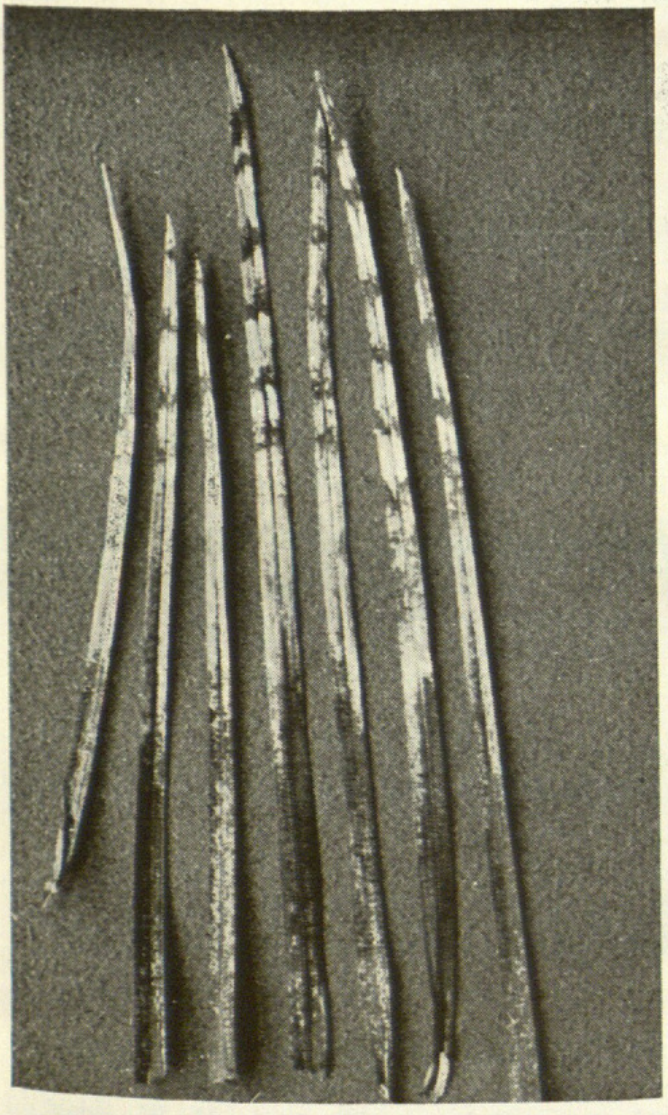
Results of a Six-Year Study of Air Pollution using Plant Indicators

Soon after the discovery that plants in the Los Angeles basin were suffering damage from air pollutants of unknown substance, it became obvious that the plants themselves would prove an excellent biological assay material for the study of air pollution (1). The affected plants were extremely sensitive, some being injured by concentrations so low that the oxidant, the most closely related pollutant measured, read only 0.10 parts per million parts of air. In contrast, eye irritation begins at approximately twice that value.



Series of bands on blades of *Poa annua* of similar age. Each white band was caused by a separate day of smog.

Plants used in the first experiments were the farm crops whose injury had resulted in severe loses to growers. They included oats, endive, alfalfa, romaine lettuce, spinach and sugar beets.

Further studies with other plants soon revealed some which proved to be more satisfactory because of their reliability and the ease with which they could be grown. Two such plants selected for this project were annual blue grass *(Poa annua)*, a common weed found in most turf, and petunia.

Selected because of its uniformity, because a large number of plants could be grown in a very small space and because it could be planted, grown, exposed and evaluated all within a period of less than six weeks, *Poa annua* offered still another important factor. The pollutant produced a band of damage within the blade of the *Poa annua* whose length was an arbitrary measure of the degree of damage. Subsequent to its selection, studies by Bobrov (2) and Juhren (3) showed this to have been a good choice.

Petunia had two advantages — it was most sensitive during those months when the sensitivity of the *Poa annua* was less sensitive and it exhibited the earliest observed symptom, silver leaf, which *Poa* did not.

"Silver leaf" injury on petunia. This was the first specific symptom observed.

At first these plants were grown in the Earhart laboratory at the California Institute of Technology. After a year or so, however, the District constructed a well-controlled greenhouse at the Los Angeles State and County Aboretum. Here it was possible to maintain reasonable control over the temperature, humidity, and day length. The plants were grown in an inert medium, vermiculite, and sub-irrigated daily with a modified Hoagland solution. Smog-free air was provided by means of large carbon filters and a positive pressure was maintained within the greenhouse so that any leakage would be outward.

Although considered as a six-year project, the period covered was more than that, since considerable preliminary work was required. One of the most important items was the construction of an exposure chamber. After three preliminary chambers had been built, the final choice was a three-compartment box of aluminum and glass. A lower compartment contained the blower and filter of activated carbon. The two upper chambers were of aluminum with glass on three sides and were identical except for the fact that one chamber received a constant supply of filtered air while the other chamber received an equal supply of ordinary unfiltered air.

Of the fifteen stations in operation, twelve were in the Los Angeles basin, one in Pomona, and two in Antelope Valley. Plants were delivered to each of these stations weekly. Six sets of ten *Poa* and two petunia each were stored in the filtered air, while one set was exposed each day in the unfiltered air and then traded for another set the next day. At the end of the week the exposed plants were brought in, and the damage evaluated and recorded. Daily maps were prepared showing the degree of injury at each station. A report covering a portion of this study has been prepared by the District (4).

Several observations may be made as a result of this project. The frequency of occurrance of moderate and heavy injury of the type which shows the symptoms of silvering and banding appears to have decreased during this period although the frequency of lighter degrees of injury may have increased. This could well be explained by the following facts (1) Extensive controls had been installed on refineries to reduce their losses. (2) The type of gasoline being marketed in the basin contained much less of the primary culprits—unsaturated hydrocarbons. (3) Blow-by devices were now installed on many vehicles. At the same time the population and the number of cars had increased and covered a large area.

It also may be noted that during the period of operation at Henniger's Flat, about half way up Mt. Wilson, damage occurring at this station was nearly as frequent as that in Pasadena. Pollution occasionally reached the Antelope Valley, undoubtedly over the mountains and through the canyons from the Los Angeles basin. Plants in the field in Del Sur showed evidence of two periods of moderately heavy injury early in 1964. At times the type of injury found at the test stations in Antelope Valley differed in some respects from that found in the basin, possibly indicating a somewhat different composition as the pollution reached that area.

Although the District terminated its work with plants early in 1962, this type of analysis has been resumed at the Arboretum and daily observations are being made in the Arcadia area.

REFERENCES

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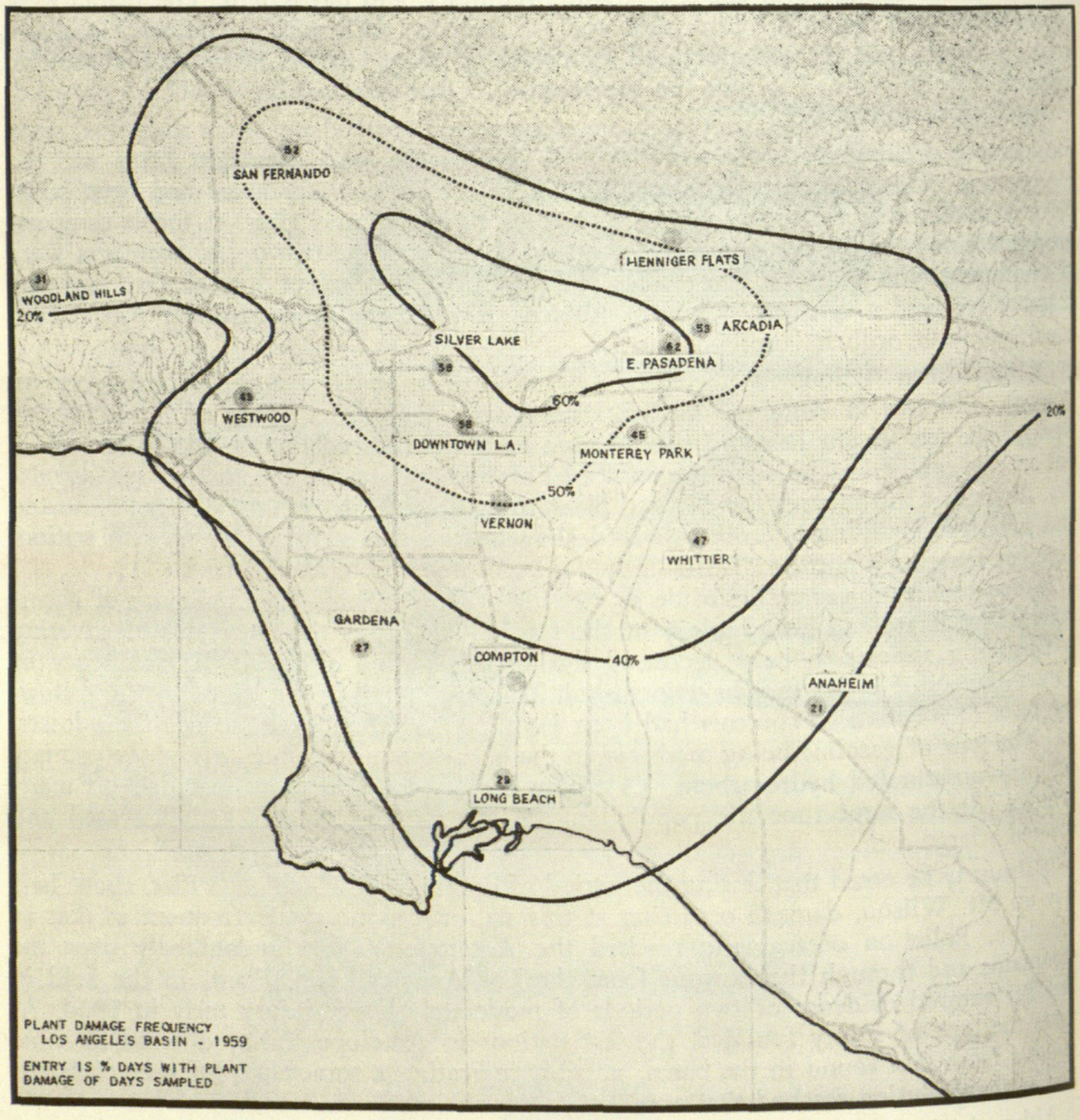
3. Juhren, M., W. Noble, F. Went: *The Standardization of Poa Annua as an Indicator of Smog Concentrations.* Plant Physiology 32:576-586 (1957).
4. Taylor, J. R., *Plant Damage Trends in the Los Angeles Basin, 1956-61.* Air Quality Report No. 47, L. A. County Air Pollution Control District.



Courtesy: Air Pollution Control District, County of Los Angeles

FACTORS AFFECTING SENSITIVITY

Basically, any environmental condition which promotes luxuriant growth will increase the sensitivity of a plant to smog. One such factor is a high nitrogen fertilizer application. Studies at the Earhart laboratory showed that well-watered plants were also more sensitive than those receiving barely enough water to prevent wilting. Taking advantage of this information, farmers in the Dominguez area have been able to grow such crops as spinach and Romaine lettuce which, although smaller and less tender, were still marketable.

A third factor affecting sensitivity is light. Although studies in this field are limited, it is apparent both from field and from laboratory observations, that a relationship exists between light intensity and degree of injury. On many plants it has been noted that sensitivity increases with shading up to a certain point and then drops off as light decreases. Again farmers have been able to use this fact to advantage. They have found that when spinach is crowded together in rows so that it grows tall and tender it is more severely injured than spinach which has been spaced so as to receive more sunlight on each plant. This reduces the yield per acre, but the crop is more marketable.

Another factor is the age of the plant. Young plants are more sensitive than mature ones. Ceanothus has been damaged in the two leaf stage. Atropa belladonna at two to eight leaves has been so severely damaged that some plants have even died while duplicate ones in filtered air have grown to maturity. At the same time others protected from smog during early growth continued to maturity in spite of repeated injury. Tree tobacco, quite sensitive in the seedling stage, appears to show little or no damage after reaching a height of about two feet. Petunia appears most sensitive around the time it is removed from flats as seedlings and replanted for marketing. This is also true of many other bedding plants. Consequently some method of protection at this stage would be of considerable help to growers. Such studies are now under way at the Arboretum.

TISSUE CULTURE STUDIES

Plant tissue culture studies related to air pollution began at the Los Angeles State and County Arboretum in 1958. These studies were conducted under the auspices of the California Arboretum Foundation on a grant from the United States Public Health Service. In the beginning, the Los Angeles County Air Pollution Control District also gave some support in the way of personnel.

The initial work was conducted by Marcella Juhren on tomato root cultures. This showed that fumigating the root cultures with naturally occurring air pollutants stimulated the growth of tertiary roots. Following this, the work was continued by Arthur Lanz employing cultures of carrot roots. Since a definite effect was noted here, a study to determine the efficacy of various substances was begun in an attempt to find something which might protect plants from smog.

When chemicals were found which seemed to show some protective ability they were tried out on intact plants. The first results of this work were reported in volume 13 of Lasca Leaves in 1963 under the title "Studies on Chemicals to Protect Plants from Smog Damage". More recent work is reported elsewhere in this issue and also in Lasca Leaves volume 14, page 74.