Plant Response to Polluted Air

specific effects of air pollutants on plants vary according to plant species and modifying internal and external factors

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Field observations—and controlled fumigation experiments—have shown that plants differ in their response to atmospheric contamination by ethylene, herbicides, fluorides, sulfur dioxide, and smog, or oxidized hydrocarbons.

Controlled experiments have also shown that plant response to air pollution varies with species and variety of plant, age of plant tissue, soil fertility levels, soil moisture, air temperatures during the prefumigation growth period, and presence of certain agricultural chemicals on leaves.

The leaves of many plants—such as tomato, African marigold, fuchsia, pepper, and potato—become curved and malformed in the presence of ethylene, while those of cantaloupe, China aster, gardenia, Cattleya orchid, and snapdragon do not. Ethylene may cause serious damage to the sepals of orchids without injury to the petals or leaves. The collapse of the sepals is often called dry sepal and is commonly found in white-flowered Cattleya and Phalaenopsis, less frequently found in dark-flowered Cattleya, and rarely found in Cymbidium, Cypripedium, and Vanda orchids.

Airborne herbicides, such as 2,4-D, 2,4,5-T, and MCP may cause serious leaf malformation in cotton, grape, tomato, melon, and alfalfa without damage to many grasses and cereals, such as barley, rice, and wheat.

Atmospheric fluorides may accumulate in many grasses, cereals, and forage crops, such as alfalfa, without damage. Fluorosis in animals may result from feeding them apparently healthy plant material containing high levels of fluorides. Other plants, such as gladiolus, grape, apricot, prune, and walnut, may show leaf injury as a result of fluoride accumulation.

Plants also vary in their susceptibility to sulfur dioxide, with alfalfa, barley, and cotton damaged at comparatively low levels, and citrus, corn, celery, and melons damaged at much higher levels.

Notable examples of variability in susceptibility to naturally occurring air pollution—or smog—were found in a field containing two varieties of Swiss chard. The Lucullus variety was severely injured by smog, while Fordhook Giant—a variety with heavily crumpled leaves and broad, thick, white stems—showed very few markings. Both varieties had been treated similarly in cultural practice.

A field planting of common bean—*Phaseolus vulgaris* — varieties Small White, Pink, Red Kidney—and of lima bean—*Phaseolus lunatus*—variety Westan, at Riverside, incurred oxidized hydrocarbon damage resulting in severe leaf injury to the Pink bean, less damage to Small White and Red Kidney, and much less damage to the Westan Baby lima.

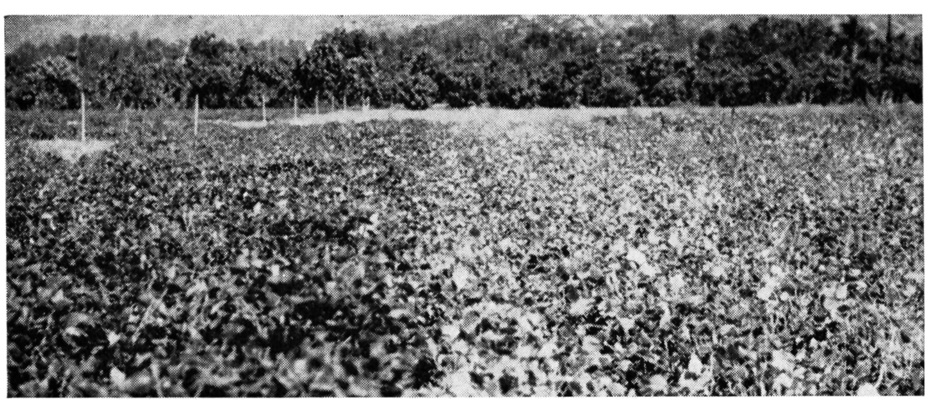
A controlled ozonated hexene—oxidized hydrocarbon—fumigation of the common bean varieties showed Mexican Red, Pink, Pinto, Scotia and Small White to be the most susceptible to injury, and Bountiful, Kentucky Wonder, and Red Kidney to be less susceptible. Fordhook Concentrated and Westan lima bean varieties were of intermediate susceptibility. The range of susceptibility and type of damage resulting from controlled fumigation by ozonated hexene is similar to that from naturally occurring oxidized hydrocarbons.

Controlled oxidized hydrocarbon fumigations of different plant species showed Pinto bean, annual bluegrass—*Poa annua*—to be highly susceptible; endive, romaine lettuce, alfalfa, sugar beet, spinach, and tomato to be moderately susceptible; and orange, lemon, Kentia palm, and Todd Mexican avocado to be less susceptible.

Field observations show that young leaves are seldom marked during periods of aggravated air pollution. The young, unexpanded leaves are typically uninjured; the mature, expanded leaves are severely injured; and the old, somewhat chlorotic leaves are rarely damaged. In grasses, where the youngest tissue is at the base of the leaf, injury first occurs at the tip, grading off in intensity of injury toward the base of the leaf. Old chlorotic leaves on grasses are seldom injured.

Controlled fumigation experiments using oxidized hydrocarbons showed that the age of the plant tissue was a critical factor in determining its susceptibility of injury. Pinto bean plants with old chlorotic primary leaves compared with plants with healthy green primary leaves were damaged only slightly, while the ones with green primary leaves were severely injured. Pinto bean plants 3, 4, 5, 6, 10, 18, 26, and 34 days from emergence were fumigated and the injury to the primary leaves was assessed. Maximum injury to these leaves developed only after plants were 10 to 18 days from emergence. There was a progressive decrease in the extent of injury with a decrease in time lapse between plant emergence and fumigation.

Natural smog damage to bean at Riverside. *Left:* resistant Westan lima bean. *Right:* badly damaged and defoliated Pink bean.



Soil Fertility Levels

Spinach, romaine lettuce, and endive grown in a glasshouse in a standard composted soil mix of low nitrogen fertility prior to controlled oxidized hydrocarbon fumigations were found to be much less susceptible to injury than a similar series receiving calcium nitrate additions at the rate of 45 pounds of nitrogen per acre. Plants not receiving the nitrogen additions were stunted, chlorotic, and showed

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symptoms of nitrogen deficiency. In contrast, plants receiving the additional nitrogen were dark green in appearance and had large succulent leaves. Damage to the latter group of plants was two to six times as severe as to those plants deficient in nitrogen supply. Similar results have been obtained with Pinto bean plants grown under a deficiency of nitrogen or phosphorus, both. Additions of these two elements sufficient to produce good growth increased the susceptibility of the plants to injury by fumigation.

Romaine lettuce and Pinto beans grown in the glasshouse under water-stress were much more resistant to fumigation injury by oxidized hydrocarbons than a similar set grown in soil with adequate moisture. Plants raised under the water-stress regime were stunted and the leaves much more leathery than those receiving adequate moisture. Field observations have confirmed the findings because it has been noted that injury due to naturally occurring air pollution of the oxidized hydrocarbon type is often more severe in recently irrigated fields or in portions of a field which received excessive amounts of water.

Air Temperature

A series of experiments has shown that plant susceptibility to air pollution injury is influenced by the temperature of the air during the prefumigation growth period. For example, spinach, romaine lettuce, and endive grown for 11 weeks at a mean air temperature of 55°F were much more resistant to injury from oxidized hydrocarbons than another set grown for the same length of time at 75°F. Total plant growth was likewise better at the warmer temperature than at the cooler temperature.

When romaine lettuce plants were grown for 10 weeks at 75°F and then transferred to the 55°F mean air temperature for one week prior to fumigation, the susceptibility was reduced by a factor of eight times. When romaine plants were grown for 10 weeks at 55°F and then moved to 75°F for the one week prior to fumigation, the susceptibility was increased by a factor of five times. Similar responses were obtained with spinach and endive although to a lesser degree.

The leaves on new flushes of growth on both sweet and sour orange seedlings were damaged by sulfur dioxide when the plants were grown in a warm glasshouse; similar flushes of growth were not damaged when they were developed outside during winter months.

Environmental influences which cause differences in plant growth also affect the susceptibility of plants to injury by some air pollutants. It appears that any single factor or combination of factors, such as high soil fertility levels, high or excessive soil moisture, and warm air temperatures, which will produce healthy, vigorous, succulent plants, will result in the development of plants which are very susceptible to damage by air contaminants.

Plants of low susceptibility may be achieved by selection of a crop known to possess some natural resistance to air pollutants and grown under a fertilization and irrigation program that is consistent with healthy growth but one that does not promote very rapid growth or very succulent foliage.

Extremely susceptible plants should be grown during the winter months when air temperatures are comparatively low and periods of aggravated pollution are less likely to occur. Resistant plants should be grown during the warm summer months.

Protective Measures

Several groups of chemical compounds are capable of preventing injury to plants caused by oxidized hydrocarbon fumigations when the chemicals are applied to the lower surface of leaves. These chemicals belong to the dithiocarbamate, benzothiazole, and thiuram sulfide groups, and have been used extensively as agricultural fungicides for the control of many fungus diseases. Two of the best chemicals for this purpose are zineb—zinc ethylenebisdithiocarbamate — and thiram—tetramethyl thiuramdisulfide.

The degree of protection is directly related to the amount of active ingredient contained in the spray or dust preparations. Protection is achieved only when the underside of leaves are adequately covered. Both groups of chemicals when properly applied to laboratory test plants protect leaves from damage from both ozone and ozonated hexene. Pinto bean leaves dusted with zineb in the laboratory and exposed to naturally polluted air near Los Angeles were protected from serious injury.

Field trials are in progress to determine whether it will be feasible to develop an economical and successful program to protect plants from natural smog damage.

Plants susceptible to smog injury and grown in glasshouses—such as many of the ornamental and bedding plants—can be adequately protected by passing the incoming air through an activated carbon filter. A number of air filters have been employed successfully on glasshouses in Berkeley, Los Angeles, and Riverside. Because the rate of air movement and residence time in the carbon

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Plants Known to Be Damaged by Air Pollutants

Crops	Susceptible	Resistant
Tree	Apricot Grapefruit Walnut	Almond Apple Cherry Date Lemon Olive Orange Peach Plum
Field	Alfalfa Oat Sudan Sugar beet	Barley Blackeyed bean Corn Mustard Black White Sweet clover Vetch Wheat
Vegetable	Bean—common Golden Cluster Pink Pinto Small white Bean—lima Fordhook 242 Beet Cantaloupe Celery Endive Lettuce—romaine Onion Parsley Parsnip Spinach Swiss chard Lucullus Tomato (some varieties) Turnip	Bean—common Bountiful Kentucky Wonder Bean—lima Concentrated Fordhook Westan Broccoli Cabbage Carrot Cauliflower Chinese cabbage Corn Cucumber Eggplant Leek Lettuce—head Muskmelon Mustard Pea Pepper Potato Radish Rhubarb Rutabaga Squash Swiss chard Large ribbed Tomato (most varieties)
Vine	Grape— Carignane Mataro Mission Palomino Pedro Ximenes Zinfandel	Grape— Concord
Small Fruit		Blackberry Boysenberry Currant Loganberry Strawberry Youngberry
Ornamental	Ageratum Carnation Chrysanthemum (some varieties) Eugenia Grass Annual rye Perennial rye Larkspur Orchid Palm— Kentia Pansy Pepper Petunia Rose Snapdragon Zinnia	Acacia Calendula China aster Chrysanthemum (most varieties) Dahlia Eucalyptus Forget-me-not Gaillardia Grass Bermuda Kentucky blue Hypericum Geum Ivy Lobelia Oak Palm— Plume Washington Stock Sweet Pea Viola White clover

LEMONS

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900 acres were planted the previous fall and winter. Also, some budding of old stumps took place. It is widely stated that some acreage of grapefruit was budded to lemons. Probably there are about 3,000 acres of new plantings of lemons in Florida. It has been reported that 50,000 boxes of Florida lemons will be processed into juice in 1956.

In Florida, as in Arizona, the production potential exists. The real impact—of the production—will be on both the fresh and processed products markets. One important reason—for California growers—for that impact is that the flow of lemons into products is not controlled in Arizona or Florida as in California. Yet important indirect effects can spill over into the fresh shipping market because—in terms of economic operations—the fresh and processed markets are more closely interrelated than they were in the prewar and immediate postwar years.

About 600 acres of lemon plantings in the California desert area can be documented, including nearly 100 acres from five to seven years old. More new lemon acreage may be in prospect for the California desert area. However, the cold winter temperature—with the resulting risk of freeze damage to the trees—is a major uncertainty and is likely to be the main limiting factor, although there seems to be some opinion that there are sufficient warm sections, as in the Coachella Valley, where lemons can be grown successfully.

As in the Yuma Mesa and the Salt River Valley of Arizona, California desert lemons are mainly a once-a-year crop, with the economic outlook depending a good deal on the strength of the lemon products market.

When potential new plantings and lemon production are considered, developments in foreign countries must not be neglected. With the economic incentive, Italian production could well increase and provide additional export surplus in the form of products destined for the American market. In addition to Italy, lemons from Chile, Spain, and Turkey enter into world commerce. The effects of such potentialities are of direct concern to the outlook for the products market as an outlet for domestic-grown lemons.

In consideration of potential production from new plantings of lemons, historically important producing counties in California—Ventura, Los Angeles, Santa Barbara, San Bernardino, Orange—require attention. Reliable data on nonbearing lemon acreage in California since 1950–51 show a relatively substantial increase for the past two years; but the total lemon acreage in the state is under the level of 10 years ago. Those earlier levels can be regained if growers anticipate profitable operations from expansion. Moreover, lemons from these sources are not fall harvested primarily for products but have direct effects on the fresh and the processed products markets.

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The second article in this series will appear in September.

ISOPROPYL

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number of orchards in the vicinity of Corona. In addition to these, a continuous history of both isopropyl ester and diethanolamine salt forms added to single annual applications of oil spray applied to mature Valencia orange trees near Tustin was available for the period of 1946 through 1953. Evidence from surveys conducted in these orchards showed that damage to the trunk bark at the soil line or other symptoms of injury had not occurred from the use of the isopropyl ester of 2,4-D.

Careful use of the isopropyl ester of 2,4-D—at the correct concentrations—on mature trees should safely give the desired responses.

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are important to the successful operation of the filters, they should be designed according to the engineering principles of air conditioning equipment.

Air Pollution Crop Survey

The occurrence and distribution of air pollutants in California were determined by reporting plant damage in a statewide experimental survey conducted in 1955. The response of plants to specific air pollutants permits the identification of toxicants, such as ethylene, fluorides, herbicides, ozone, sulfur dioxide, and oxidized hydrocarbons, or smog. Although instruments are available for the measurement of ozone, sulfur dioxide, and some atmospheric oxidants, there is no suitable instrumental measuring system for ethylene, fluorides, herbicides, and the airborne toxicants which cause oxidized hydrocarbon damage.

The survey covered 40 field and glasshouse-grown crops and eight sensitive weeds. A total of 2,668 reports from 51 counties showed 544 cases of plant damage due to air pollution in 12 counties in and about the San Francisco and Los Angeles areas.

Results of the air pollution crop survey in California in 1955. Solid black areas report plant damage; lined areas report no plant damage. No reports received from white areas.

The air pollutants responsible for plant damage are recognized in decreasing order of importance as smog or oxidized hydrocarbons, ethylene, fluorides, and sulfur dioxide. Smog is widely distributed within the air basins associated with urban development. Fluorides are apparently distributed near and on specific industrial sites. Ethylene seems to be confined to urban areas, although this may be due in part to the fact that ornamental plants, such as carnation and orchid, are usually grown near large population centers. Sulfur dioxide damage rarely occurred and was usually confined to specific industrial locations.

Surveys of economic loss to agriculture in the affected areas are in progress.

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