Plant Damage by Air Pollution

visible injury to plants by atmospheric pollutants amounts to annual loss of millions of dollars in some affected areas

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Production and quality of an important number of field, flower, fruit, ornamental, and vegetable crops—in many of the important growing areas of California—are adversely affected by air pollution.

Visible injury to 11 crops in the Los Angeles area has caused losses exceeding $3,000,000 annually since 1953. No estimates have been made of economic loss from reduced growth and lowered production in the absence of visible injury. Development of protective measures and abatement programs is essential for some relief from losses due to air pollution.

The air-borne toxicants responsible for most of the crop damage are ethylene, fluorides, herbicides, oxidized hydrocarbons, ozone, and sulfur dioxide, and can be identified by plant response. Examples of plant response are shown in the illustrations on the following two pages.

Ethylene

Ethylene occurs as a gaseous contaminant in air from chemical manufacture, vehicular traffic, and some other combustion effluents.

Leaves of some plants, such as marigold, do not develop normally in the presence of 5 pphm—parts per hundred million—of ethylene in the air, whereas 10 pphm cause leaf abnormality in tomato. Leaf irregularities and poor flower formation occur in narcissus and tulip at concentrations above 400 pphm. Failure of carnation flowers to open properly and flower drop in snapdragon have been attributed to the toxicity of ethylene. Although the foliage of orchids is not appreciably affected by ethylene, the sepals of many Cattleya and Phalaenopsis flowers wither and dry when exposed to 5 ppb—parts per billion.

Fluorides

Soluble fluorides—either in the vapor or solid state—cause leaf injury to a wide variety of plants including apricot, forage grasses, gladiolus, grape, and prune.

Controlled fumigations with hydrogen fluoride at concentrations less than 10 ppb produced leaf damage in gladiolus and grape after one to two weeks but no injury to foliage of sweet orange seedlings after several months.

Gladiolus leaf tips quickly die and turn brown. The discolored and necrotic area slowly expands downward until at maturity about half the leaf is affected. Irregular, discolored bands are sometimes produced on affected leaves. The extent of damage depends on the amount of fluoride accumulated in the leaf, the environment in which the plant is grown, and the variety exposed.

Dead and discolored tissue usually first appears at the margins of grape leaves, then gradually spreads inward. Sometimes the red and brown areas are separated from the green portion of the leaf by several concentric bands of discolored tissues; in other cases there is no such transition zone. Marginal killing and discoloration of grape foliage are sometimes erroneously referred to as burn or scorch. Only the older leaves of Mission, Thompson Seedless, and Palomino are affected, whereas both young and old leaves of Blue Elba, Burger, and Mataro show injury.

Leaf symptoms observed on fumigated gladiolus and grape were indistinguishable from those observed in the field in the vicinity of industrial fluoride sources.

Sweet orange seedlings showed no injury symptoms after four months of continuous fumigation which caused obvious damage to gladiolus and grape. Chemical analyses indicated that fluoride had accumulated in the citrus leaves, but the relative amount present was much less than that in gladiolus or grape leaves and about the same as in spring flushes of orange foliage of comparable age collected in the field near a known atmospheric fluoride source.

Herbicides

Herbicides have been extensively used since the introduction of 2,4-D in 1945. Production of the 2,4-D acid in 1946 was about five million pounds; in 1948 it reached 20 million pounds and thousands of operators had applied the herbicide to some 40 million acres. It was not unexpected that air pollution—through misuse of the chemical—occurred.

Injury to cotton plants resulting from 2,4-D was reported in 1945, to grapes in 1948. Since then, studies of the various manifestations of 2,4-D injury have clarified the relation of formulation, temperature, wind, application methods, and plant specificity to crop injury. Seriously damaged crops have included cotton, grapes, blackeye peas, tomatoes, melons, broccoli, sugar beets, lettuce, alfalfa, and a host of flower and ornamental plants.

Severe accidental crop damage resulted from the use of volatile esters of 2,4-D before it was realized that the fumes could be carried by air currents.

Researchers at Davis have shown that deformation of cotton and grape leaves may result from a millionth of a gram—or less—of 2,4-D. The application of more than 15 millionths of a gram to one cotyledon of a cotton plant brought permanent injury to the plant. In terms of cotton culture this means that one gram—$\frac{1}{28}$ ounce—of 2,4-D applied directly to the plants would produce leaf deformation on all the plants on 25 acres; 15 grams—about $\frac{1}{2}$ ounce—would injure them permanently.

Because indiscriminate use of 2,4-D threatened the grape and cotton industries in certain areas of the state, the California Department of Agriculture formulated regulations governing the use of 2,4-D, 2,4,5-T, MCP, and 2,4-D and 2,4,5-T propionic acids. These regulations list crops subject to injury, describe the hazardous areas within the state, the time and conditions for use of injurious herbicides, prohibit use of aerosol and dust forms of injurious her-

Concluded on page 12

Fumigation chamber used in exposing plants to controlled air pollution.

Discoloration of leaves of Utah 10B celery caused by natural smog.

Bronzing of grapefruit leaf caused by exposure to Los Angeles smog.

Silvering of spinach leaves caused by smog.

Smog damage to field-grown Romaine lettuce.

Dock (Rumex) leaf glazed and colored by smog.

Grape leaf damaged by controlled fumigation with hydrogen fluoride.

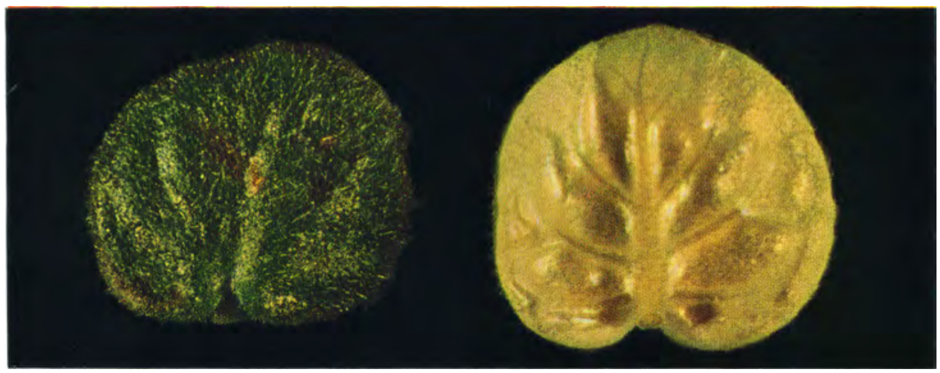
Chlorotic areas of cheeseweed leaf resulting from exposure to smog.

Pinto bean leaves typically damaged and discolored by smog.

Dry sepal damage of Cattleya orchid due to atmospheric ethylene.

Cattleya sepals, but not petals, damaged by atmospheric ethylene.

Alfalfa leaf drop resulting from smog.



Collapsed, brown, and glazed African violet leaves occurring on glasshouse-grown plants.

Smog damage to sensitive annual bluegrass.

Chlorotic barley leaves caused by smog.

Gladiolus leaf damage by fluorides from the air.

AIR POLLUTION

Continued from page 9

bicides, prohibit use of volatile forms of these except for an isolated region in San Luis Obispo County, and define the requirements for permits of use.

The occurrence of crop damage from air pollution by herbicides has become very much reduced with the introduction of the amine, heavy ester, and emulsifiable formulations of 2,4-D, 2,4,5-T, and MCP, and a widespread program of education among commercial applicators of herbicides.

Smog

Smog—oxidized hydrocarbons—injury to plants is distinctly different from crop damage by ethylene, fluorides, and herbicides. The leaves of celery, lettuce, spinach, African violet, and some other vegetable, field, and flower crops usually show a silvering and glazing on their lower surfaces, sometimes followed by a bronze or reddish discoloration. Damage to the upper leaf surface occurs when the lower surface is severely injured and excessive amounts of water are lost. Similar symptoms are produced on weeds which may be used as indicator plants for the presence of oxidized hydrocarbons in areas not producing economic crops.

Chlorotic blotched and streaked areas develop on the leaves of cereals and forage grasses after exposure to oxidized hydrocarbons. If the exposure is to a high concentration of toxicant or for a long period at low levels, light tan to brown discolored areas develop in the leaves.

Alfalfa is very sensitive to damage from oxidized hydrocarbons, resulting in the production of dead areas on the leaves, followed by leaf drop. Serious alfalfa crop failures frequently occur in the southern part of California during periods of aggravated air pollution. The aftereffects are easily seen because the plants retain only a tuft of leaves at the tip of bare stems.

Symptoms of crop damage observed in the field can be reproduced experimentally by fumigating susceptible plants with a mixture of ozone and refined petroleum, such as gasoline.

Grapefruit and lemon leaves have been injured by controlled fumigation with a mixture of ozone and hexene, a constituent of gasoline. Injury from ozonated hexene has not been observed on navel, Valencia, and sweet or sour orange seedlings.

Fumigations of eight hours—with a concentration of toxicant approximately six times higher than that found on a very smoggy day—caused leaf drop and graying and silvering of the lower surface of grapefruit leaves; lemons were not injured in the same fumigation. However, leaf drop and brown coloring of the lower surface of lemon leaves did occur after 13 daily fumigations of seven hours each with artificially contaminated air approximating that of a severely smoggy day. The injury was confined to new growth which developed during and immediately preceding fumigation on trees pruned heavily and grown in a glasshouse equipped with an activated carbon filter. Valencia orange seedlings fumigated at the same time did not show injury.

Leaf drop and bronzing of portions of the lower surface of grapefruit leaves occurred during a two months exposure to natural air pollution in the Los Angeles area. Small grapefruit trees exposed to this pollution dropped 36% of their leaves, while control trees, exposed to filtered air, lost 6% of their leaves. Two leaves from one of the control trees developed bronzing, suggesting that the filter system may not have been adequate for complete protection.

Oxidized hydrocarbons are widely distributed in agricultural districts adjacent to metropolitan areas and appear to be responsible for most of the crop damage.

Ozone

Ozone is reported to be present in abnormally high concentrations in the Los Angeles and San Francisco Bay areas. Although ozone under controlled experimental conditions is extremely damaging to vegetation in concentrations below 30 pphm, there is no evidence that this pollutant is responsible for much crop damage. The leaves of plants exposed to ozone become bleached, chlorotic, and may collapse, but no glazing, silvering, or bronzing of the lower leaf surface occurs.

Sulfur Dioxide

Sulfur dioxide is one of the oldest known air pollutants and its effect on plants has been studied for more than 75 years. Relatively high concentrations cause acute injury wherein the marginal or interveinal tissues of leaves collapse, dry out, and are bleached white in a short time. Veins of affected leaves remain green. Concentrations not high enough to cause acute symptoms may cause chlorotic markings.

Leaf markings on alfalfa, one of the most sulfur-dioxide sensitive plants, first appear when plants are exposed to 1.25 ppm—parts per million—for one hour; severe damage occurs in one hour at 5 ppm. Exposure at 0.4 ppm causes damage in about seven hours. Some workers have shown that concentrations

Complex equipment required for accurate releasing of pollutants into fumigation chamber.

of 0.1 to 0.3 ppm will not mark the leaves of plants.

Plants vary in their sensitivity to sulfur dioxide. Alfalfa, barley, and cotton are about equally sensitive. Other plants require a greater exposure for comparable levels of damage. For example, oats require 1.3 times the exposure, beans, wheat, and carrots 1.5 times, cabbage 2 times, corn 4 times, celery 6.5 times, and muskmelon almost 8 times the exposure required to injure alfalfa. Environmental conditions that tend to increase succulence of plants will also increase their sensitivity to the gas.

The level of sulfur dioxide in the south coastal plain of California has been reduced to such a point that damage to plants no longer occurs except where accidental spilling of the gas occasionally occurs around some industries. Concentrations in air near Los Angeles now vary from 0.01 ppm to 0.24 ppm and average about 0.06 ppm.

The effect of atmospheric pollution by these six recognized air-borne contaminants upon the agricultural economy of California is serious, because there is visible crop damage, reduction in yield and quality, and an increase in the cost of production.

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Photographs by Ken Middleham, University of California, Riverside.

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