Smog in the South Coastal Area

injury to herbaceous plants in the affected area found to be result of air pollution by gases and aerosols

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Smog injury to crops in Los Angeles County in 1949 amounted to an estimated loss of $479,495.00.

Crop damage by smog was first noted in 1944, when certain vegetables in Los Angeles County were observed to have leaf injury.

Subsequent study revealed the injury to be a problem of general air pollution with the area affected including important parts of Los Angeles, Riverside, and San Bernardino counties and nearly all of the agricultural sections of Orange County.

The term, smog, is widely used to describe a mixture of smoke and fog which is not unusual or confined to any particular region. It is more descriptive to refer to a similar condition in the south coastal area of California as air pollution. The condition in that area is unique and has developed with population and industrial expansion during and since the recent war years.

Causes of Air Pollution

Visible air pollution is formed by a peculiar set of air phenomena in the affected area which is bounded by mountain ranges to the north and northwest, and by low ranges of hills and mountains to the east and southeast. These barriers confine the air pollutants from a thickly populated, highly industrialized area within a rather restricted zone.

The primary phenomenon is a warm air stratum which is part of the Pacific inversion layer and frequently present in the area. This stratum acts as an invisible lid which prevents the smoke, fumes, dusts, and gases originating in the basin from dispersing into the upper atmosphere. The bottom of the inversion level usually exists at 1,000 to 3,000 feet above sea level.

The Pacific inversion layer rises and lowers according to the meteorological conditions affecting it. Occasionally the base of the inversion layer drops below 500 feet above sea level. When this lowered ceiling is accompanied by several days of low wind velocity, so that stagnant air accumulates beneath the lid, smog develops. During the daylight hours there is usually a westerly breeze of low velocity which moves the air mass eastward. This air mass must escape through three natural outlets—Mint Canyon, Cajon Pass, and San Gorgonio Pass—to desert areas where it is dispersed.

Injury to plants occurs only during periods of aggravated air pollution. This aggravation is brought about by the lowered ceiling and reduced wind velocity. Air pollutants during a smog are concentrated in a smaller volume of air than is normally available. Wind velocity at this same time is likewise less than its normal rate. This increased concentration of the pollutants generally causes susceptible plants to show symptoms of smog damage within one to three days.

Types of Air Pollutants

At least three types of air pollutants are known to occur in the Los Angeles area: gases; aerosols; and particulate matter.

The gas phase is the most common cause of plant damage. Occasionally, especially during periods of foggy weather, plant injury results from the deposition of an aerosol containing toxicants. There is evidence that particulate matter is released into the atmosphere, but no evidence that this material is responsible for plant injury. The liberation of particulate matter may, however, play an important part in the formation of aerosols which later become laden with toxicants. Minute dust particles are known to behave as condensation nuclei for various types of aerosols.

Actual analyses of the atmosphere in Los Angeles County during smog periods, by the Stanford Research Institute and the Los Angeles County Air Pollution Control District have shown that the following constituents are present: sulfur dioxide, ammonia, oxides of nitrogen, sulfur trioxide, aldehydes, filterable oils, soluble chlorides, carbon, ozone, hydrogen sulfide, traces of many minerals and elements, organic peroxides, acrolein, fluorides, methyl chloride, formic acid,

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Topographical map of California's south coastal basin, showing the extent of air pollution—lightly shaded area—and the area of heaviest concentration of air pollution, where the greatest economic loss of vegetables occurs—darker shaded area. Stippled areas represent incorporated cities. Arrows indicate the direction of normal air flow out of the basin into the adjacent desert areas, the darker arrows signifying the main outlets.

sodium chloride, and gaseous hydrocarbons. Sulfur dioxide, a common air pollutant in several districts in the United States, is present in subtoxic concentrations in the Los Angeles area and is not considered to be the primary cause of plant damage in this area.

On the basis of symptom expression and of the existing concentration of hydrogen fluoride in the Los Angeles air pollution, there is no indication that this compound is responsible for plant damage.

Symptoms

The initial symptom of plant injury—which develops 24 to 72 hours after exposure to the gaseous component of air pollution—is a glazed appearance on the under surface of the affected leaves.

On crops such as spinach, garden beets, Romaine lettuce, and chard, the glazing is silvery like that due to freezing injury. Endive and turnips affected show initially a bleaching of the lower leaf surface rather than a glazing, which often develops into light-tan necrotic areas.

Microscopic examination of these affected areas shows that the protoplasts of the mesophyll layer of cells, especially in the region of the stomata, have collapsed, and that large air pockets have taken their place. These air-filled spaces are responsible for the glazed or bleached appearance of the leaves. The epidermal layer is not initially affected.

Under certain conditions, which may be due to low concentration of the air pollutants or a short exposure period, no further symptoms develop. Usually, however, there is progressive dehydration of leaf tissue in the affected region until scorched areas develop through the entire thickness of the leaf and leave brown necrotic spots with glazed margins.

The leaf scorching develops across veins and is not limited in area by any anatomical leaf structure. Under severe and prolonged attacks the entire leaf may be so affected.

The aerosol component of air pollution damages plants in a different manner. This type of damage is usually seen only during periods when heavy air pollution is accompanied by fog. The surface of a plant may be wet by the precipitation of fog particles, which presumably contain air pollutants of an as yet undetermined nature. Under these circumstances the sequence of symptom development is one in which the exposed surface, usually the upper surface, shows the initial necrosis. The pH—the measurable alkalinity and acidity—of the leaf-surface moisture, which is between three and four, indi-

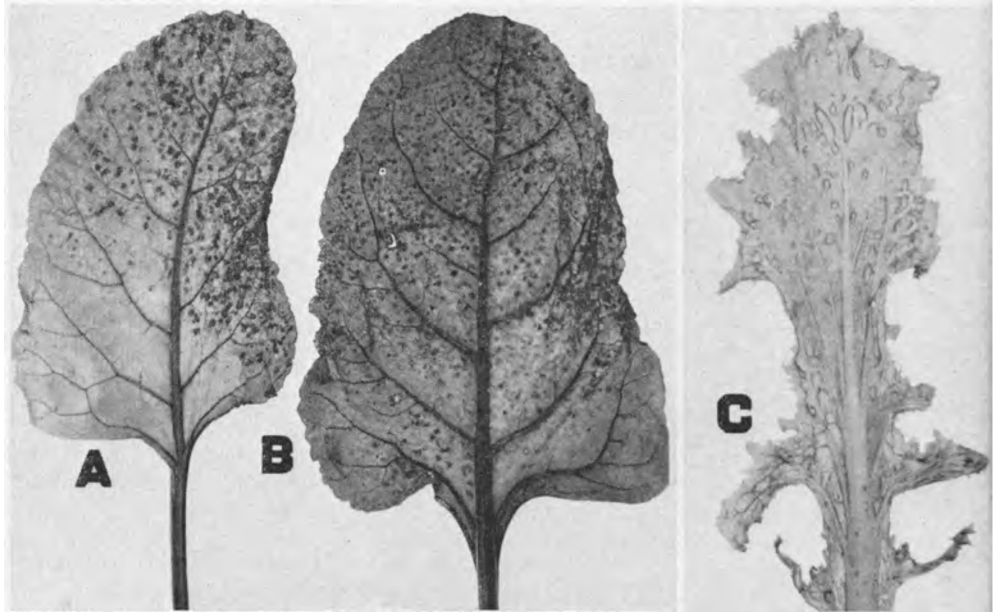


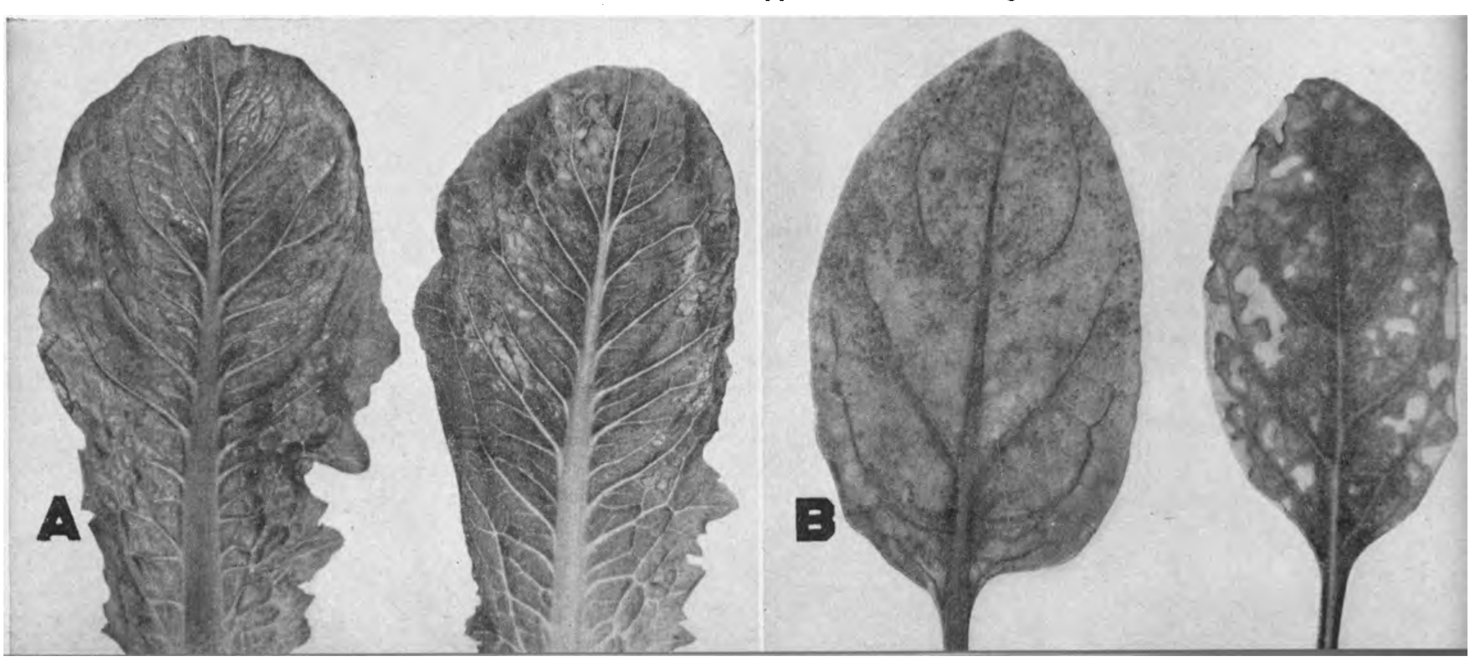
Table beet leaves *left*, showing aerosol injury on both top *A* and bottom *B* surfaces of le leaf area. The lower left-hand area of leaf *A* was protected by a covering leaf. *Righ* bleaching of lower leaf surfaces and a subsequent tan to bronze color of dried-out tissu

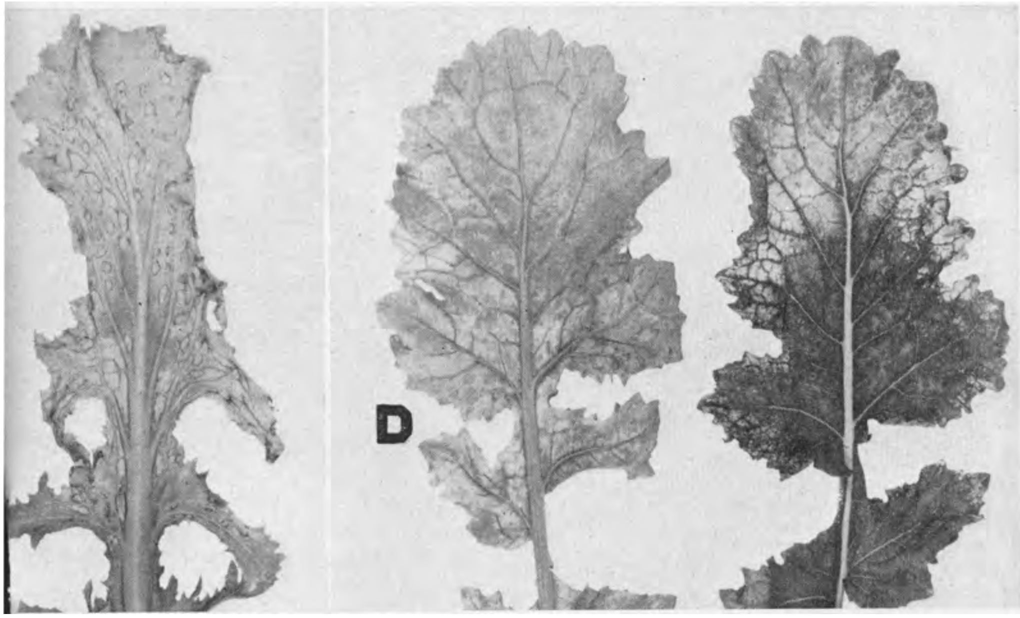
Economic Loss to Susceptible Crops Caused b 1949, Showing Acreage Affected, Average Yie

Crop	Total acres planted*	Acres affected
Alfalfa	**53,400**	**9,000**
Spinach	**3,380**	**1,000**
Parsley	**300**	**300**
Celery	**2,300**	**100**
Romaine	**500**	**300**
Endive	**350**	**275**
Radish	**750**	**500**
Turnip	**750**	**300**
Table beets	**700**	**250**
Mustard greens	**600**	**200**
Chard	**50**	**40**
Total		

* Information from Annual Crop Report of the Los A

Gaseous air pollution injury to leaves of *A*, Romaine lettuce; *B*, spinach; *C*, garden beet; and *D*, Swiss chard. The lower leaf surface is shown on the *left*, and the upper surface on the *right* in each case.





The small punctuate spots characterize this type of injury, uniformly dispersed over the eaves of endive C and turnip D, showing gaseous air pollution injury manifested by initial The latter symptom is visible on both upper, left, and lower, right, surfaces of each group.

ir-Pollution Damage in Los Angeles County in s, Estimated Damage, Unit Value, and Dollar Loss.

cent tal cted	1949 average yield per acre*	Per cent loss	Dollar value per unit*	Total dollar loss
7	5.3 tons	15	$24.00	$171,720.00
0	5.1 tons	50	33.50	85,425.00
0	500 crates	25	1.50	56,250.00
4	950 crates	25	2.00	47,500.00
0	300 crates	25	1.50	33,750.00
9	300 crates	20	1.40	23,100.00
7	400 crates	10	1.10	23,000.00
0	500 crates	10	1.00	15,000.00
6	300 crates	10	1.50	11,250.00
3	400 crates	10	1.00	8,000.00
0	450 crates	25	1.00	4,500.00
....				$479,495.00

es County Agricultural Commissioner.

cates the presence of a relatively strong acid. Cellular collapse in many small spots develops progressively through the upper epidermis, mesophyll, and lower epidermis of the leaf, leaving scorched areas similar to those caused by the gaseous component.

No glazing or bleaching accompanies this injury. Leaf areas covered by exposed leaves show no markings and thus give further evidence that this type of injury is due to the precipitation of a phytotoxic agent from the atmosphere.

The gas-type injury may be confused with sulfur dioxide injury by an untrained observer. The distinct bleaching or loss in chlorophyll of the leaf in interveinal areas—and not across the veins—in sulfur-dioxide injured plants is not found with the gas-type of air-pollution marking. In addition, when lists of plants susceptible to injury by sulfur dioxide and gaseous smog are compared, it is evident that host susceptibility is distinct for each type.

Alfalfa is extremely susceptible to sulfur-dioxide injury, but only moderately so to gaseous air pollution.

Squash and cucumbers are easily injured by sulfur-dioxide, while apparently untouched by gaseous smog.

In general, most members of the mustard-type plants—the Cruciferae—are uninjured by gaseous air pollution but are marked by sulfur-dioxide. Controlled fumigation by sulfur-dioxide has in no instance given any sequence of symptom development such as that described above, and it has failed to produce the characteristic glazing of under surfaces of leaves. This latter symptom is the most reliable indication of gaseous smog damage to crops in the southern California area.

Economic Losses

The greatest economic losses due to air pollution are experienced in those crops in which the foliage is the salable portion of the plant, such as lettuce, alfalfa, and spinach.

During certain periods in 1949 entire fields of spinach were unharvested because severe leaf scorching made the crop unmarketable.

In some alfalfa fields in southeastern Los Angeles County, leaf drop reduced yields of fall cuttings by 50%. The market value of the damaged hay was greatly lowered because of the high proportion of stems to leaves. In a few fields the last cutting was sufficiently damaged to make it unprofitable to be cut for hay.

Other crops such as table beets, tur-

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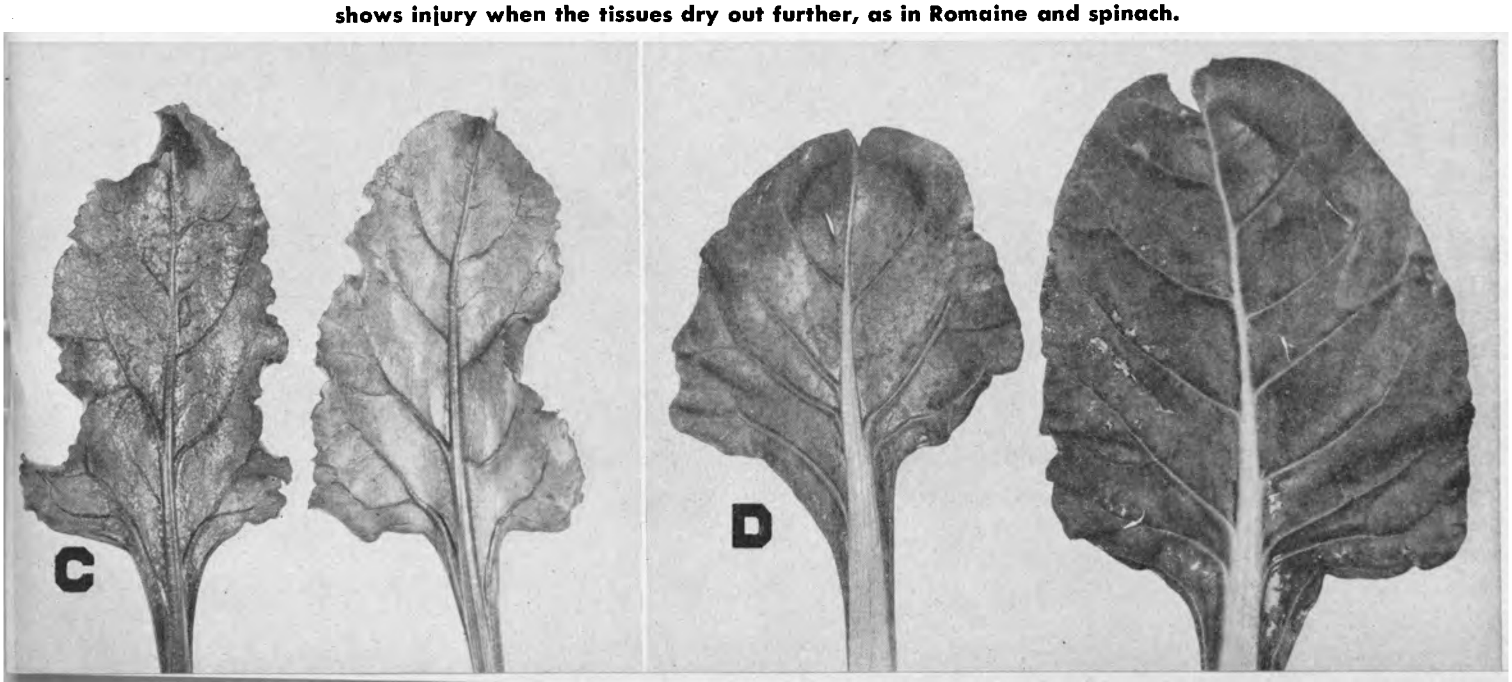
Note that the lower surface shows the initial stages of injury characterized by a glazed appearance; the upper surface shows injury when the tissues dry out further, as in Romaine and spinach.



SMOG

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nips, and radishes also were damaged by smog. The roots or edible portions of these crops were uninjured, but severe burning and spotting of the tops lowered market value because of poor appearance.

In the table on pages 8 and 9 crops are listed in the order of dollar-value loss due to smog damage.

In the case of alfalfa, only 17% of the Los Angeles County acreage is produced in the area seriously affected by air pollution. The greater portion of the acreage is north of the Sierra Madre Mountains in a desert area far removed from industrial and urban centers. In the case of other crops, such as spinach and parsley, 20% to 100% of the acreage is located in the area of heavy concentration shown in the dark-shaded portion of the map on page 7.

Estimates given in the table are for total 1949 production. Individual crops of spinach may have been a total loss at the particular time they were scheduled for harvest, whereas at other times during the year spinach was undamaged. The same is true of all other crops listed.

In addition to the listed crops there were others that showed damage but evaluation of dollar loss would be exceedingly difficult. For example, the leaf tips of young oats, barley, and onions were scorched. However, these crops overcame the injury sustained during early growth and eventually produced a near-normal yield. Destruction of leaf tissue resulted in delayed maturity in some instances. The longer growing period necessitated additional irrigation, fertilization, pest control, and weeding for crops such as beets and onions. No attempt was made to calculate these losses.

Many types of flowers and ornamental nursery stock—in greenhouses as well as out of doors—have at times had either leaves or flowers, or both, marked by concentrated air pollution. In most cases, the market value was lowered because of poor appearance, and estimates of loss by members of the flower industry ranged from one half to one million dollars. There are no surveys or other reliable data to substantiate these estimates.

The following cultivated plants are listed in order of decreasing susceptibility: *Extreme*—Romaine lettuce, endive, and spinach; *Moderate*—beet, celery, oats, Swiss chard, and alfalfa; *Slight*—barley, onion, parsley, radish, tomato, turnip, and rhubarb; *None*—cabbage, cantaloupe, carrot, cauliflower, cucumber, pumpkin, squash, and broccoli.

A number of weeds also have been damaged by air pollutants, namely: wild oats, *Avena* sp.; lambs quarters or pig weed, *Chenopodium album*, and *C. murale; Malva parviflora* and annual bluegrass, *Poa annua*. Weeds are used as an indication of the extent of air pollution injury because they are often found in zones not ordinarily cultivated. Annual blue-grass is the most susceptible plant observed to date.

Injury to herbaceous plants has been recorded in a triangular area delineated by the cities of Santa Monica, San Clemente, and Redlands. The agricultural districts most seriously affected are those south and east of Los Angeles.

Air pollution damage to susceptible crops is particularly devastating, and is comparable to such catastrophies as fires, frosts, and floods, because it can render a crop worthless almost overnight, with no previous warning. It is a direct function of the weather and of meteorological conditions of the southern California coastal plain. This fact alone makes the problem a difficult one to solve.

Since crops differ in degree of susceptibility to injury, it may be advisable for growers in this area to revise their crop schedules by eliminating the extremely sensitive plants. This will have to be done in order to stabilize their economy until such time as the phytotoxic agent or agents of air pollution are definitely identified and eliminated.

Elimination of the components of air pollution will require diligent research to solve the engineering problems involved, and also will require the establishment of new regulations governing air pollution and means for their enforcement.

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The above article is based on Paper No. 640, University of California Citrus Experiment Station, Riverside.

SYSTEMIC

Continued from page 3

Studies on systemic insecticides will require several years of experimentation—and the solution of many technical problems—before any practical use can be anticipated. Among the many questions to be answered, the following are readily apparent: *1*, duration of effectiveness at various concentrations to a variety of citrus pests; *2*, most suitable methods for application—whether by foliage spray, irrigation, pressure injection, or soil treatment; *3*, distribution of compounds in citrus plants and possible toxicity of treated fruit to consumer; *4*, distribution of soil applications through the root zone of citrus trees and its effects on soil fertility and possible deleterious effects on citrus or other crops.

Experimental set-up for growing lemon seedlings in water cultures containing systemic insecticides.

Because the answers to many of these questions are difficult to obtain—due to the extremely small amounts of compound present—it is planned to use radioactive molecules as tracers. Such studies should increase current knowledge of insect and mammalian toxicology. They should be valuable also in elucidating the principles governing the translocation and distribution of organic molecules in plant tissues.

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The above progress report is based on Research Projects Nos. 1078 and 1415.