AIR POLLUTION DAMAGE TO AGRICULTURAL CROPS

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AIR POLLUTION damage to agricultural crops has been recognized for some years. This type of damage is usually associated with a particular industrial process or specific source for the air-borne contaminant. Damage to the foliage of a variety of crops can be caused by exposure to sulphur dioxide, fluorides, chlorine, and ammonia. These chemicals usually cause a specific type of damage on certain crops, such that the air-borne chemical can be recognized by the symptom expression on the plant affected. Injuries of the kind suggested above have been reported from many places throughout the world. Damage to crop plants in the vicinity of Los Angeles were first found to be of importance in 1945. The symptoms of damage were different from those usually associated with recognized air pollutants. Not only were the symptoms different but the kinds of plants affected were usually different. This suggested that perhaps a new type of air-borne chemical was present that was responsible for the injury to crops grown in the Los Angeles area.

A survey conducted in 1944 and 1945 demonstrated that damage was first observed in the vicinity of Dominguez and North Long Beach, California. The principal crops affected were those not normally troubled by sulphur dioxide or fluoride contaminants. The expression of injury was also different. Vegetable crops such as celery, spinach, and lettuce showed a silvering and slight glazing of the lower leaf surface. Sometimes it was followed by a bronzed discoloration. Although the silvering and glazing of the lower leaf surface was often the only symptom, there were sometimes cases of leaf damage to the upper surface. It was discovered that damage to the upper leaf surface was always associated with water loss by the lower surface. These same types of symptoms have been found on a variety of other cultivated plants as well as weeds.[1] Using both weeds and crop plants as indicators, it has now been observed that this type of air pollution damage can be found from the Mexican border to Santa Barbara and inland in the vicinity of the San Gorgonio pass. The same type of damage has been observed since 1950 in the San Francisco bay area. Although damage to plants in the bay area is less extensive than in the Los Angeles area, it is now known to occur from San Rafael on the north to Gilroy on the south and eastward to Walnut Creek.[2] Further surveys may indicate a more extensive area to be affected.

The specific type of damage observed on particular crop plants was known to occur only during periods of reduced visibility and complaints of human distress. These periods are locally known as "smog periods." As a result of this some people refer to the damage of plants as "smog damage." Since the term "smog" is coined from the words smoke and fog, neither of which is responsible for damage, it is not proper to call the damage observed on plants "smog damage," but rather "air pollution damage." It was felt that, if the toxicants responsible for crop damage could be identified, perhaps some measures for abatement leading to relief from the air pollution problem in the Los Angeles area could be effected. As a result of this interest, several research agencies[3] initiated a program which resulted in the finding, reported by Haagen-Smit, etal.[4] that the toxicants in the air responsible for crop damage are oxidized hydrocarbons. Hydrocarbons come from the manufacture, handling and use of gasoline, i.e., refineries, service stations, storage tanks, and automobiles,—or, generally speaking, from refined petroleum products. The vapors of these hydrocarbons from both their manufacture and use escape into the atmosphere and become oxidized. It is the oxidized hydrocarbons that are responsible for the silvering and glazing of specific crop plants. The hydrocarbons, principally unsaturates, cause no injury by themselves. They must be oxidized to give the damage factor.

Concentrations of oxidized hydrocarbons sufficient to cause injury to crop plants occur only during periods of aggravated air pollution. These periods are caused by the lowering of an inversion layer of air that confines the pollutants given off by normal industrial and community activity. The pollutants are confined below the inversion layer and due to the topography of the Los Angeles basin, must necessarily spread eastward and southward, since the mountain barriers prevent their escape into the adjoining desert regions. The air pollution period becomes more aggravated the longer the inversion layer remains low. When the inversion layer rises above the normal levels and permits the air to be broadly distributed, there is no longer important pollution present. A similar situation pertains in the San Francisco bay area. The periods of air pollution in San Francisco are of shorter duration and of lower concentration largely because the mountain areas are of lower elevation and the wind velocities higher. The same conditions for air pollution exist throughout the Pacific coast slope, but it is only in areas with large metropolitan populations and a topography that permits the pollutants to become trapped that crop damage occurs. Since the discovery, by the senior author, of air pollution damage caused by pollutants other than sulphur dioxide and fluorides, and the discovery later by Haagen-Smit, that the specific pollutants responsible for crop damage were oxidized hydrocarbons, the University of California, Riverside, has conducted a great deal of research attempting to discover how agricultural crops can be grown in an area receiving a polluted air mass. Our research studies are also concerned with knowing more about the chemical behavior of air pollutants in the atmosphere using plants as an assay method.

Observations on damage to crops by several writers have shown that there is a great variation in their relative susceptibility to injury by oxidized hydrocarbons. Our studies are still incomplete, particularly with regard to forage plants, flowers, and woody ornamentals, and tree crops. Weeds that are common to the area and that have been observed to be damaged are: annual Bluegrass, Cheese Weed, Chick Weed, Dwarf Nettle, Lambs Quarters, London Rocket, Quick Weed, and Wild Oats. There are more than 50 other weeds that could be enumerated but which may not have general distribution. The relative susceptibility of a variety of plants known to be damaged by the oxidized hydrocarbons is given in the table on page 9.

Some plants such as lettuce, tomato, and sugar beets fail to grow normally in the polluted air mass, and yet, show no visible injury symptoms.[5] Since all plants grown in the area are subject to this growth suppression, it is impossible to measure what effect this reduction in growth has upon plant vigor and yield. The effect of this growth suppression can be readily demonstrated by growing plants in a box, separated so that one group of plants receives normal polluted air, and another receives air that has been filtered through activated carbon. Within the short period of a week a growth difference can be observed in tomatoes under such an experimental design. Research is now current at Riverside to determine the effect of this growth suppression upon tree crops such as citrus and avocado.

Observations of crop damage in the field, particularly by J. Hurst, West Covina, revealed that plantings receiving adequate and regular water supplies through irrigation were more severely damaged than those not so well watered. The same differences have been reproduced experimentally under controlled fumigation and regulated water supply in cooperative experiments with S. J. Richards at Riverside. It is possible for a grower who has the option of withholding water during a short pollution period, to minimize crop damage by exercising the option to delay irrigation until after the aggravated air pollution period has passed. Obviously if the period is of long duration, water cannot be withheld. Perhaps practical use can be made of this finding by relating irrigation schedule to

Plants Known to Be Damaged by Olefinic Peroxides in Smog

Crops	Susceptible	Resistant
Tree		Grapefruit Lemon Orange
Field	Alfalfa Oat Sudan Sugar beet	Barley Blackeyed bean Mustard Black White Sweet clover Vetch Wheat
Vegetable	Bean—common Golden Cluster Pink Pinto Small white Bean—lima Fordhook 242 Beet Celery Endive Lettuce—Romaine Onion Parsley Parsnip Spinach Swiss chard Lucullus Turnip	Bean—common Bountiful Kentucky Wonder Bean—lima Concentrated Fordhook Westan Broccoli Cabbage Cauliflower Chinese cabbage Corn Eggplant Leek Lettuce—head Muskmelon Mustard Pea Pepper Potato Radish Rhubarb Swiss chard Large ribbed Tomato
Ornamental	Chrysanthemum (Some varieties) Grass Annual rye Perennial rye Larkspur Petunia Snapdragon	Calendula China aster Chrysanthemum (Most varieties) Dahlia Forget-me-not Gaillardia Grass Bermuda Kentucky blue Lobelia Pansy Stock Sweetpea Viola White clover

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forecasts of air pollution periods.

Kendrick and others[6] discovered that additions of nitrogen to the soil increase the susceptibility of plants to damage by the oxidized hydrocarbons. This reveals that efforts to produce a good crop provide the optimum opportunity for damage by the air pollutants.

Under controlled fumigation conditions it has been demonstrated that the amount of damage to a particular plant is directly related to the length of fumigation or exposure to a given concentration of the oxidized hydrocarbons. The longer the exposure the greater the damage, even at concentrations as low as 0.1 parts per million. These observations corroborate those made in the field which show that damage to crops is directly proportional to the length of the pollution period.

There is another additive feature and that is that the lower the inversion layer, the greater the damage. This increased damage is due to the fact that there is less total air to receive the pollutants which are responsible for plant damage. As the inversion layer, or lid, goes up, there is a greater air volume present to receive the pollutants, and therefore less total concentration per unit of air, yet the same amount of pollutant in the total mass. Air pollution is important in the Los Angeles basin because there are approximately 265 days a year in which the inversion layer is low enough to permit accumulation of toxicants which can cause plant damage and be annoying to humans as well as to reduce visibility. Were it not for the inversion layer, the mountain barriers, and the prevailing westerly breeze of low velocity, there probably would be no real air pollution problem in the Los Angeles area. There are other cities in the United States and in the world with as many people and more per square mile that do not yet have this particular problem. The uniqueness of the problem in Los Angeles and San Francisco is attributed to the inversion layer, the topography, the size of the metropolitan area, and the use of refined petroleum products.

Various methods for protecting plants against air pollution damage are being studied. Protection of susceptible plants against damage from the oxidized hydrocarbons can be afforded by the producer of glass-house grown plants, by introducing air into the glass-house through an activated carbon filter. If this circulation system is adequate, there will be a positive pressure maintained within the glass-house which will exclude the polluted air mass. The activated carbon filter is a highly effective method of removing the oxidation products of refined petroleum vapors. Naturally, this same type of carbon filter can be used in the home if the vapors are

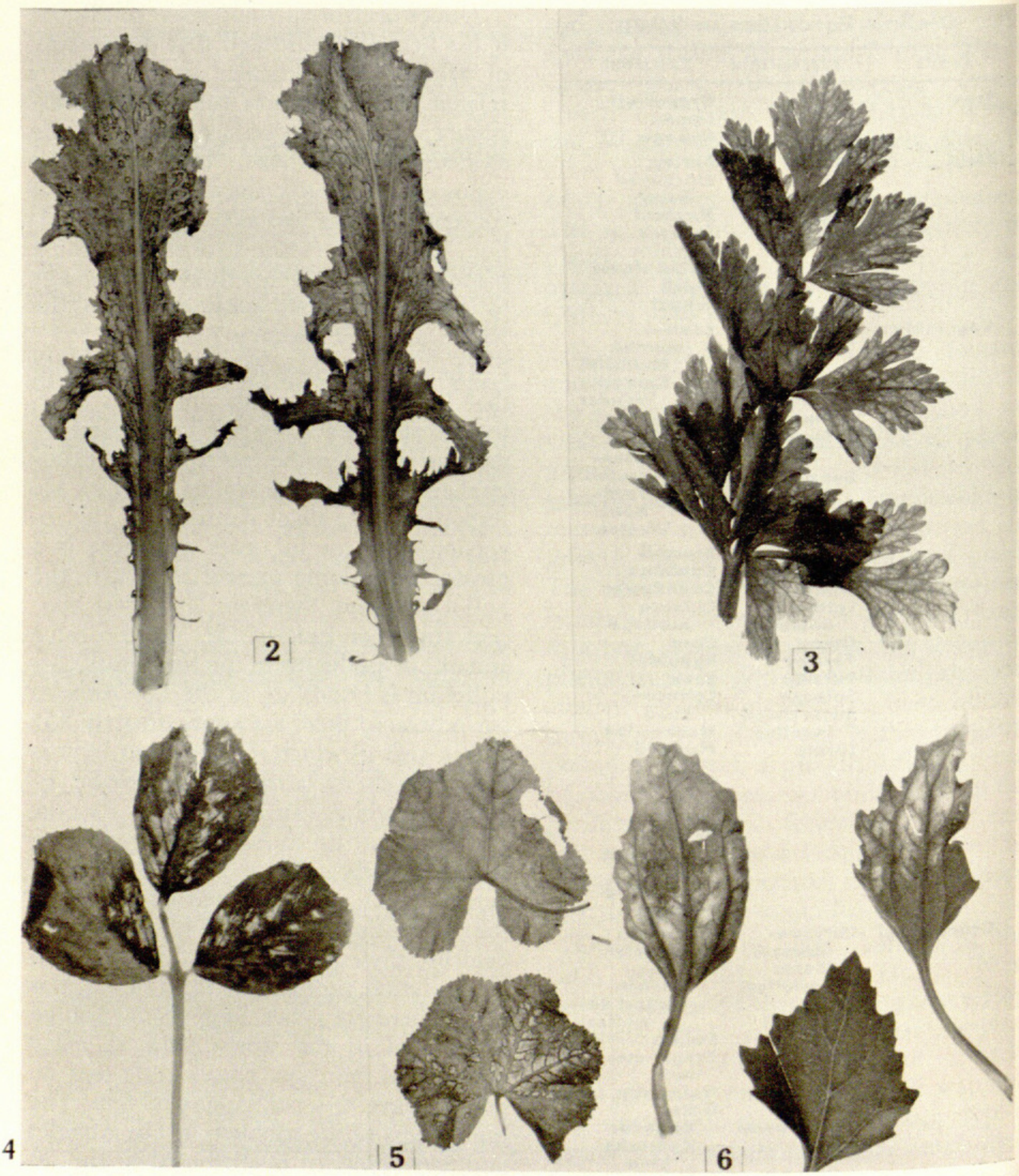

Figure 2. Endive Lettuce. (Left) Type of damage observed on the upper leaf surface. (Right) That observed on the lower. Figure 3. Natural damage on celery caused by oxidized hydrocarbons. Figure 4. Natural air pollution damage on alfalfa. Figure 5. Damage to cheese weed. (Upper) Healthy leaf. (Lower) Naturally affected by oxidized hydrocarbons. Figure 6. Chenopodium. The upper two leaves showing silvering and glazing as found on the lower leaf surface. The lower leaf shows no damage on the upper leaf surface.

to be excluded for a private residence or even a public building. Protection can be afforded to plants grown in the field by the application of dithiocarbamates to the leaf surface. This class of material offers specific protection from damage by the oxidized hydrocarbons. Some dithiocarbamates are currently available on the market at moderate price. One that is commonly sold as a fungicide for the control of leaf blights is zinc ethylene bis-dithiocarbamate. This same material is often referred to as zineb. Zineb is sold under a variety of trade names but can always be recognized by reading the list of active ingredients on the package. Research has not progressed sufficiently to indicate at this time just how often the dithiocarbamate should be applied to plant material sensitive to oxidized hydrocarbons, or in what quantity.

The abatement of hydrocarbon losses from the air mass is difficult to accomplish and time consuming because of the multitude of contributors. The effects of air pollution damage are real to the agriculturist and cause great economic loss. Damage to 11 agricultural crops in 1949 in the Los Angeles area alone was estimated at slightly less than ½ million dollars. Estimates based on surveys in 1953 indicate that losses will exceed three million dollars. This increase in loss is due not only to recognizing damage on a greater variety of plants but also due to increased community activity and industrial development. It is hoped that the results of the air pollution research activity at the University of California at Riverside will permit some identification of oxidized hydrocarbon injury to plants in other parts of the world, and some immediate relief to the producer of food, forage, and flower crops, grown in the Los Angeles and San Francisco areas.

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In California, it is neither aggressive nor of great size, but is an unusually arresting shrub of 6′-10′ across with rounded heart-shaped leaves which vary greatly in size from 2″-12″ in diameter, leathery, and with edges entire or scalloped, the upper sides rather smooth, varying in color from green through bronze to red, sometimes with conspicuous ribbing. In seasons of very cool nights, the foliage is even more brightly hued, though the plant is virtually evergreen unless damaged by frost of which it is definitely tolerant. This foliage color is the outstanding feature of *Hibiscus tiliaceous* in the Los Angeles area, one not observed on it in tropical climates. Flowers, 2″-3″ long, open as yellow cups, some with dark eyes; later in the day, they deepen to apricot or dull orange; by night, to dull red. The inflorescence is not profuse, nor is it conspicuous. Of rather easy culture, in fairly rich soil, it prefers a *warm* location, free of strong winds. The authority of the plum color of *Hibiscus tiliaceous* may be emphasized to advantage by a companion planting of *Echeveria metalica,* (perhaps as a ground cover), or *Phormium tenax,* variety Silver Bronze.

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