Effects of Air Pollutants

controlled air pollution studies reveal injury to certain important processes of plant life by air-borne toxicants

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Symptoms of plant damage in the field can often be identified as the effect of one or more air pollutants. However, the exact mechanisms whereby the plant is damaged and the various manifestations of damage—after fumigation with air toxicants—are not so well known.

Some forage and vegetable crops—alfalfa, common bean, garden and sugar beet, lettuce, spinach, and tomato—grow and yield poorly in the polluted atmospheres of the Los Angeles and San Francisco areas. Reduced growth and production can occur without leaf necrosis.

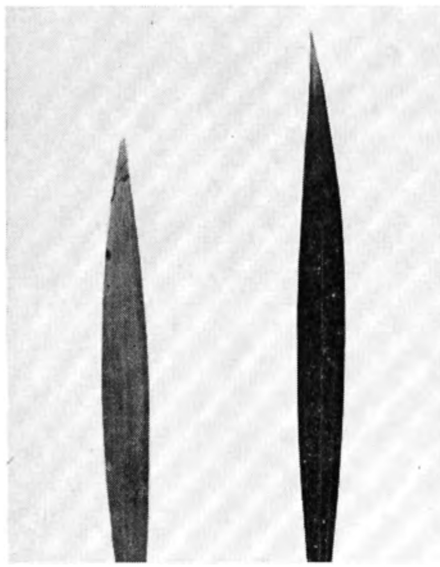
Field plants grown in controlled atmosphere enclosures and subjected to synthetically polluted air show reduced growth, while plants of the same varieties grown in enclosures receiving clean, carbon-filtered air do not show reduced growth. Differences in height and weight of the plants are noticeable after less than a week of exposure and become pronounced after three weeks. Artificial pollutants may also cause a decrease in growth that is not accompanied by visible leaf damage.

Bountiful and Red Kidney varieties of beans fumigated with ozonated gasoline at an oxidant concentration of 0.7 ppm—parts per million—for three hours on eight different days over a 10-day period, did not increase in height as fast as the control or check plants. Fresh and dry weights of the fumigated plants were less than one half those of the plants growing in clean air. The amount of trifoliate leaf area was one third that of the controls.

As little as 10 ppb—parts per billion—of hydrogen fluoride in a controlled fumigation chamber given over a 30-day period to Blue Elba, Mataro, and Burger grapes caused considerable killing of leaves with a resulting decreased growth rate. Flower production of gladiolus exposed to the same fumigation with hydrogen fluoride was greatly reduced. Plants that did flower had only a few florets per spike. Citrus trees grown for four months under the same conditions—10 ppb of hydrogen fluoride—grew at the same rate as trees in a house free of hydrogen fluoride and showed no visible damage to the leaves.

Effect of Ozonated Hexene and Ozone Alone on the Respiration of Lemon Fruits. Based on the Respiration Rate Four Hours After the End of the Treatment.

	Ozonated Hexene	Ozone
Length of treatment	Stimulation of respiration	Stimulation of respiration
Hrs.	%	%
2	12	13
4	28	14
15	50	26



Kentia palm. ***Left:*** **small, chlorotic leaf from palm grown in unfiltered glasshouse.** ***Right:*** **large, dark-green leaf from palm grown in carbon-filtered glasshouse.**

The growth of plants exposed to hydrogen fluoride gas was not decreased unless visible leaf damage had occurred. The decreased growth is probably due to the loss of photosynthetic capacity.

Effects on Plant Life Processes

Photosynthesis—one of the important processes of plant life—is simply the production of energy-rich sugars from carbon dioxide and sunlight. The only way a plant can grow is to produce its own energy through photosynthesis. Plant cells that have been killed form necrotic or dead areas—visible damage from gaseous toxicants—and cannot participate in the plant's process of photosynthesis.

A small aquatic plant—*Lemna* or duckweed—was chosen for studies on the measurement of the effects of air pollutants on photosynthesis because it could be grown under carefully controlled conditions. The plants were exposed for various lengths of time to ozonated hexene at an oxidant concentration of 0.2 ppm. Visible damage occurred on the plants after a one-hour exposure to this gas. Photosynthesis was reduced 10% after four hours' exposure to ozonated hexene and 67% after an exposure of 24 hours. When duckweed plants were treated with air containing 1.0 ppm of ozone, photosynthesis was reduced 5% after four hours and only 38% after 24 hours' exposure. Therefore, ozonated hexene is more effective in reducing photosynthesis than is ozone.

Because the inhibition of photosynthesis could be due to a destruction of chlorophyll, analyses were made of the chlorophyll content of the same plants used for the photosynthesis measurements. After treatment with ozonated hexene for four hours, the chlorophyll content was reduced only 4%, but after 24 hours it was 49% less than in the controls. When the plants were treated with ozone, about 5% of the chlorophyll was lost after four hours but 40% had disappeared by 24 hours. When the plants were fumigated with hexene alone, there were essentially no effects on either photosynthesis or chlorophyll content.

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Effect of Ozonated Hexene and Ozone Alone on Photosynthesis and Chlorophyll Content of *Lemna* Plants.

	Ozonated Hexene		Ozone	
Length of treatment	Inhibition of photosynthesis	Disappearance of chlorophyll	Inhibition of photosynthesis	Disappearance of chlorophyll
Hrs.	%	%	%	%
4	10	4	5	5
12	53	26	27	21
24	67	49	38	40

Effect of Repeated Doses of Ozonated Hexene and Ozone on the Respiration of Lemon Fruits. Fifteen-Hour Fumigations. Based on the Respiration Rate Four Hours After the End of the Treatment.

	Stimulation of respiration			
	Ozonated Hexene		Ozone	
	Dark green fruit	Light green fruit	Dark green fruit	Light green fruit
	%	%	%	%
One fumigation	50	27	26	21
Two fumigations	71	24	45	17
Three fumigations	86	45	68	53

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Respiration—another important process in plant life—enables plants to utilize the energy produced in photosynthesis for carrying on such functions as growth. A measure of respiration can be obtained from the output of carbon dioxide by the plant. If this process is upset, the plant may no longer be efficient in its use of energy and there is less food available for growth and other functions.

The effects of ozonated hexene and ozone on the respiration of lemon fruit were studied. Ozonated hexene concentrations—0.2 ppm of oxidant—and 1.2 ppm of ozone, when ozone only was used, stimulated respiration after a 2-hour fumigation. The stimulation obtained after a 15-hour treatment was much greater, particularly when the fruit was treated with ozonated hexene. The fruit appeared to respire faster after being treated with these gases on three consecutive nights. Whether this stimulation of respiration is harmful to the fruit is unknown. The respiration of bean plants was stimulated also to about the same extent as the lemon fruit. Duckweed plants responded but to a smaller extent.

A third important process in plant life is the maintenance of permeability of membranes enclosing all plant cells. It is suspected that some air pollutants seriously disrupt membrane permeability, thereby causing death to the cell. Table beet tissue exposed to ozonated hexene caused a change in cell permeability that permitted the anthocyanin pigment of the beet to diffuse out when the tissue was placed in water. Further experiments with bean leaf tissue and potato tuber tissue showed that ozonated hexene first caused a decrease in permeability followed by an increase in permeability. Bean leaves failed to show visible damage from this pollutant until the stage of increased permeability was reached, indicating that the damage which is observed—water soaking of the leaves—may be due to this change in permeability.

Growth Suppression

Adverse changes in the life processes such as photosynthesis, respiration, and cell permeability may result in growth suppression without visible injury.

Many plants are stunted when fumigated with ethylene gas although other pollutants—such as sulfur dioxide—cause no reduction in growth of plants other than that caused by loss of leaves due to killing.

However, because the growth suppressive effects of air pollution upon tree and woody crops were not known, studies were made using Kentia palm and avocado.

Kentia palms—produced in the vicinity of Los Angeles in the last six years—have been reported to be abnormally small and chlorotic. Some of these commercially produced palms were obtained for experimental use in Riverside. No noticeable additional leaf injury was produced by exposing some of the palms to ozone alone or to a mixture of ozone and gasoline vapor. The remaining plants were divided into three lots, one placed in a lathhouse, a second in an unfiltered glasshouse, and a third in a carbon-filtered glasshouse.

Eight months later the palms in the lathhouse remained unchanged and were small with chlorotic leaves. The palms in the unfiltered glasshouse were somewhat larger and less chlorotic than those in the lathhouse. The palms in the carbon-filtered glasshouse were noticeably larger, averaged one leaf more than the palms in the ordinary glasshouse, and the leaves were longer and dark green in color. Exclusion of the naturally occurring air pollutants in Riverside by carbon filters enabled the palms to regain a healthy, normal color and to grow more rapidly than those not protected with carbon filters.

Avocado trees were grown in air polluted with oxidized hydrocarbons—smog—and in clean air for six months to see if they were susceptible to growth reduction like that occurring in the herbaceous plants and Kentia palms.

Mexican avocado—Todd strain—seedlings were grown in soil in 10″ clay pots. Thirty-six pots were placed in each of two fumigation chambers which were glazed on five sides and were about 6′ cubes. The air passing through the chambers was washed with water and filtered with activated carbon and was free from all air-borne plant-damaging agents. One set of trees was exposed to clean air only, while the other set was exposed to clean air and daily additions of synthetic pollutants derived from mixing ozone with gasoline vapor. Monthly measurements were made of stem length and diameter. Spinach, sugar beet, and tomato plants were placed in the fumigation chambers at various times and consistently showed leaf injury after a single day of exposure.

There was no leaf injury to the avocado leaves after six months of fumigation, but the leaves of trees receiving only clean air were also free from injury.

The stems of the fumigated trees had an average increased length of $8\frac{1}{2}$″ and an average increased diameter of 0.13″. The average increase in length of stems

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***Todd Mexican avocado seedlings. Left:* grown in polluted air. *Right:* grown in clean air.**

Kentia palm. *Left:* grown in unfiltered, standard glasshouse; *Right:* grown in carbon-filtered, standard glasshouse; at Riverside.

OLIVE

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fect flowers was reduced from 32% in the check to 17% by removing half of the leaves and to 11% by complete defoliation. On the other hand, the removal of potential inflorescences months before bloom resulted in a substantial increase in perfect flowers in the remaining buds. In 1952, where there were four leaves to each bud, the per cent of perfect flowers was as high as 63%, as compared with 24% where there was only one leaf for each inflorescence.

Although complete defoliation considerably reduced the per cent of perfect flowers, some normal ones still developed. Apparently this was because the reserve materials stored in stems and branches were translocated and utilized in the development of the flowers. However, if there are leaves nearby, they contribute toward even better development of the pistil, and this beneficial effect is increased as the number of leaves increase.

The experiments at Davis indicate that cultural practices—such as shading from overcrowding, nutrient deficiencies, or disease conditions such as peacock spot — *Cycloconium oleaginum* — that tend to cause loss of leaves and therefore a decrease in the number of perfect flowers should be avoided. Whereas, if cultural practices are directed toward the retention of as many healthy leaves as possible, a higher proportion of perfect flowers—and thus a greater fruit set—can be expected.

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DEER

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cated starvation or to starvation brought on by the deterioration of their teeth.

The sex ratio of fawns at birth was determined from a sample of fetuses to be 11 males to eight females, giving a ratio of 137.5 males to 100 females. Even though the sample was small, it was considered fairly indicative.

However, during the die-off in the exceptionally severe winter of 1951–52, early and midwinter fawn losses ran to nearly 400 males to 100 females, but later in the winter more females died to bring the over-winter average to 210 males to 100 females.

The winter of 1951–52 had a high rate of rainfall, low temperatures and heavy parasite infections. During the three subsequent winters, conditions were generally milder, with the exception of the 1954–55 winter which was cold but with little rainfall. The average sex ratio of the fawn losses from natural causes for these three winters was 100 males to 100 females, which indicates that fundamental differences appear to mitigate variously against the sexes, depending on environmental circumstances.

In general, it is evident that under the conditions encountered at Hopland, parasites can contribute significantly to losses of fawns during their first winter and, to a lesser extent, to the losses of yearlings during their second summer. Few older deer carry sufficient number of worms to be affected. Likewise, the magnitude of losses involving parasitism can be increased by severe weather and overstocked conditions.

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of unfumigated trees was 9⅛″ with an average increase in diameter of 0.16″. Although the stem diameter in the fumigated trees was significantly smaller than in the unfumigated ones, there was no real difference in the height of the two sets of trees.

Reduced growth in the Mexican seedlings has been caused in six months by exposure to ozonated gasoline. Because the effects produced by controlled air pollution are usually indistinguishable from those caused by natural pollution, growth reduction in field-grown trees may be expected. Field tests are scheduled to determine the effects of pollution on growth and production of commercial avocado varieties.

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WALNUT

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pean red mite became noticeable on July 29. Controlling the pest at this time did not appear to greatly influence the quality of the crop at harvest. Regardless of mite control, better quality was obtained from OMPA treatments than from the plot treated with Systox. The same situation held in orchard *B* where plots treated with OMPA produced better quality nuts than the Systox plot.

Serious spider mite populations have failed to develop where Systox has been used in the spring to control the walnut aphid. However, its direct use to control spider mite infestations in late season is in need of further investigation. This is particularly true in regard to the dosage required.

OMPA applied in the spring to control the walnut aphid has in all cases resulted in excellent control of the Pacific spider mite. This has not proved to be the case in regard to the European red mite, and threatening populations of this species have developed where OMPA has been used.

Serious spider mite populations are not likely to develop before August. Where it is apparent that natural enemies will not take care of the situation, control measures should be applied. Adequate control of the Pacific spider mite with conventional sprayers has been obtained where 15% wettable aramite powder was used at the rate of 1.5 pounds per 100 gallons of water and applied as a thorough coverage spray.

Control of the Pacific spider mite should result from treatment by air carrier sprayers with 12 to 14 pounds of aramite 15% wettable powder applied in from 400 to 500 gallons of water per acre. For the control of the European red mite, the aramite wettable powder should be increased to two pounds per 100 gallons where applications are made with conventional sprayers. With air carrier sprayers the amount should be increased to 15 to 18 pounds per acre. In all cases, satisfactory control of spider mites is dependent upon thorough coverage.

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MAPPING

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attention to watering. Preplanting fumigation or change of rootstock may also be indicated.

The relatively high incidence of B condition trees points toward root trouble and suggests further investigation of cultural and irrigation practices as they affect root health.

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