Air pollution has been defined as the presence in the outdoor atmosphere of substances in concentrations sufficient to interfere directly or indirectly with man’s comfort, safety, health, or the full use and enjoyment of his property. Common manifestations of air pollution resulting from man’s contamination of the atmosphere include restriction of visibility, damage to property, irritation of the senses, adverse effects upon health, and plant injury.

Plant damage from phytotoxic gases has been recognized for more than a hundred years. At first the greatest concern such as smelters, chemical plants, industries dealing with paper, clay and glass products, and the combustion gases from large scale users of fossilized fuels such as coal and petroleum. The earliest recognized plant toxics were relatively simple substances such as sulfur dioxide, hydrogen fluoride, carbon monoxide, and ethylene.

**Sources of Plant Damaging Air Pollutants**

More recently, in the period since World War II, an additional group of new and more complex substances have been implicated as important constituents of polluted atmospheres. The most widespread and important of these substances result from the oxidation of hydrocarbons and may be developed as a result of a dark reaction between ozone and olefins or the photo-chemical breakdown of nitrogen oxides and hydrocarbons in the presence of ultraviolet light.

Hydrocarbons are present in the air as a result of incomplete combustion of fuels by industrial and domestic users and to an even greater extent as a waste product from motor vehicle operation. Nitrogen oxide is produced by the combination of nitrogen and oxygen in the air by any hot combustion source such as industrial boilers, home furnaces, open fires, or auto combustion chambers. Ozone is produced in the air by the action of the ultraviolet rays in sunshine on nitrogen oxide in the air giving nitric oxide plus ozone. This reaction is reversible, but if hydrocarbons are present in the air to remove the nitric oxide from the scene, a buildup of ozone occurs. Another injurious gaseous component called peroxyacetyl nitrate (PAN), an unstable organic nitrogen compound, is formed by the irradiation of gaseous mixtures containing simple olefins and nitrogen oxides with natural or artificial sunlight. At concentrations of less than 1 ppm (part per million) in the atmosphere this substance will induce plant symptoms similar to those caused by oxidant air pollution, but different in some respects from the damage caused by ozone-olefin gas mixtures reacted together in darkness. PAN is the first specific compound that has been isolated from photochemical reaction mixtures to give typical symptoms of oxidant injury on susceptible plants. It is also a strong eye irritant, so can account, at least in part, along with formaldehyde and acrolein—two other known eye irritants—for the eye irritation characteristic of photochemical air pollution.

**SYMPTOMS OF PLANT INJURY CAUSED BY AIR POLLUTANTS**

**SULFUR DIOXIDE**

This is one of the oldest known air pollutants. Sulfur dioxide commonly results from the smelting of ores and the combustion of coal and petroleum having some sulfur content. Old time florists who burned poor quality soft coal, and who had their boiler in one corner of the greenhouse will remember the sulfur dioxide injury that occurred nearly every winter in their establishments.

Typical injury symptoms of sulfur dioxide consist of irregular interveinal or marginal dead spots in the leaf tissue bleached white or straw color (sometimes brown) in color. Veins of the affected leaves normally remain green. The affected areas are usually dry and papery in texture resulting from the initial collapse of spongy parenchyma cells and the subsequent disruption of the upper palisade cells of the leaf. Damage is local in nature, not systemic.

Plant susceptibility to sulfur dioxide injury is directly related to relative humidity of the atmosphere, the damage being worse at higher moisture levels. Open stomata are likewise normally necessary for severe injury to occur, and environmental conditions favoring stomata opening (bright light, high moisture levels in the soil, and so on) intensify injury. The sulfur dioxide absorbed by the leaf cells unites with water to form the phytotoxic sulfate. Later this is slowly oxidized to the innocuous sulfate form, and in some instances chemical analysis of the foliage to detect the level of sulfates has been used as a part of the diagnosis. Alfalfa, barley, and cotton are especially sensitive indicator plants for sulfur dioxide injury, and will respond to levels of 0.5 to 1.0 ppm in the atmosphere.

**ETHYLENE**

This gas has been known to cause plant injury since 1901 when it was implicated by a Dutch research worker. In earlier times, it was an important constituent of manufactured illuminating gas, and frequent occurrences of plant injury resulted from accidental gas leaks in the greenhouse area. Natural gas, as a fuel source, on the other hand, normally contains such low levels of ethylene that we rarely encounter bonafide damage to plants today from small gas leaks. Ethylene does result, however, from some chemical manufacturing process (e.g. polyethylene manufacturing plants), from the normal respiratory processes of many kinds of living plant material, and

Air Pollution (continued from page 3)

probably in greatest total quantities from automobile exhaust.

Unlike the other air pollutant gases, which cause tissue
collapse, ethylene typically interferes with the normal ac-
tion of the endogenous (internal) growth regulating sub-
stances within plants. As a result some typical symptoms
include growth suppression, abnormal epinastic growth
(bending down) of stems and leaves, increase in stem di-
Ameter, leaf or flower abscission, and abnormal flower
development. In some instances, loss of apical dominance
and the promotion of lateral bud development occurs.
Some plants exposed to this gas lose their ability to or-
ient properly to gravity, with growing stems assuming
horizontal positions instead of vertical, and in at least one
instance, it has been reported that roots grew up out of
the soil, into the air above, rather than downward as is
normal.

Flower crops are particularly susceptible to ethylene in-
jury. Shattering or shelling of the florets of snapdragons
and calceolarias, “sleepiness” in carnations, premature aging
and petal fall in cut roses, “dry sepal” in orchids, and
the yellowing and abscission of rose leaves infected with
the black spot fungus are all examples of the damaging
effects that ethylene gas can exert on these ornamental
plants. Marigold plants are one of the most sensitive
plants known, epinasty of leaf petioles occurs on plants
exposed to 0.017 ppm ethylene in the atmosphere.
Tomato, an easier test plant to grow during dark winter
periods, responds to levels of about 0.05 ppm. Any florist
who suspects he might have an ethylene problem would
be well advised to keep a few young, vigorously growing
tomato plants spotted at strategic spots around his green-
house regularly—particularly during the winter heating
season, when minimal greenhouse ventilation is being car-
ried out.

FLUORIDES

These are emitted as waste products from smelting, cer-
ic, glass, and clay manufacturing industries and from
aluminum, chemical, and phosphate plants. Gaseous hydro-
gen fluoride is the most TOXIC PRODUCT PRODUCED.
Fluoride injury normally results from accumulation of the
toxic material in the leaves of the plant. Apparently,
translocation of fluorides is unidirectional in the leaf,
with concentration of the toxicant in the tips and mar-
gins of the leaves. When toxic concentrations are reached,
the spongy parenchyma and palisade cells again collapse
as in the case of sulfur dioxide injury, but in this instance
the most severely affected areas will be at the tips and
margins of the leaf.

There is some question as to whether or not it is neces-
sary for stomata to be open for fluoride accumulation in
the leaf. Injury from night fumigation of the plant may
be just as severe as from treatment during the day time
hours. The normal symptom displayed by the damaged
plant will be necrotic tissue at the tip or edge of the leaf.
The margin between the dead and living tissue is sharp,
and is often accentuated by a darker brown-red band of
color. Plants susceptible to fluoride injury have very low
tolerance levels for this ion and necrosis will often result
at leaf tissue concentrations of 50 to 200 ppm, while re-
sistant species may tolerate levels of up to 500 ppm with-
out any apparent injury. Gladiolus (especially light col-
ored varieties) are particularly sensitive to fluoride in-
jury, and have been injured experimentally by fluoride
concentrations in the ambient atmosphere as low as 0.1
to 0.2 ppb (parts per billion).

OXIDANT SMOG

At first termed "smog" injury, this plant injury is now
more correctly described as "oxidant" damage. Typical
symptoms include silvering, glazing, or bronzing (and
sometimes necrosis) of the lower leaf surface of the
youngest fully expanded leaves. Normally, damage to the
upper surface of the leaf will occur only after the lower
(stomate bearing) surface has been severely damaged.
The silvering of the leaf surface results from death of a
single layer of cells just under the epidermis, and their
subsequent separation from the remainder of leaf by a
layer of air.

Tobacco and petunia leaves collapse throughout the
thickness of the leaf, and the injured area may often be in
more or less distinct bands across the leaf. This signifies
differences in susceptibility of different portions of the
leaf depending upon age and maturity of the cells, since
in the plants cell growth ceases first at the tip of the leaf
and later at the base. The distal portion of the leaf is
then, relatively more mature than the basal portion.

Symptoms indistinguishable from naturally occurring
oxidant injury on test plants having been secured by fum-
igating plants with gases produced by reacting ozone with
a wide variety of olefins at high concentrations in the
dark, and then diluting the end products in an airstream.
Neither ozone alone, nor the final end products of the re-
action (aldehydes and organic acids) produced typical
oxidant injury symptoms; therefore it was concluded that
the injurious components were transitory intermediate
products, possibly ozonides or peroxides. To date, the ex-
act identity of these substances has not yet been deter-
mined.

Basically similar results were obtained by treating
plants with the photochemical reaction products of nitro-
gen oxide and olefins—injury corresponding to that
caused by naturally occurring oxidants. The product re-
sulting from this reaction, however, has been isolated,
purified, and identified as peroxyacetyl nitrate (PAN),
and represents the first chemically characterized substance
among the "oxidant" group of phytotoxicants.

The injurious substance(s) formed in the dark from
combination of oxone and olefins is not the same as PAN,
however, since there are slight differences in the response
of Pinto bean test plants to fumigation with the two pol-
lutants. The primary leaves of 14-day old plants were
severely injured by the dark reaction product, but were
unaffected by the photochemical reaction product, PAN.
Plant damage can be caused by concentrations of PAN of
0.1 to 0.5 ppm after a few hours exposure. Petunia ro-

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maine lettuce, Pinto beans, and annual bluegrass are some of the most sensitive indicator plants for oxidant damage.

ENVIRONMENTAL FACTORS AFFECT SUSCEPTIBILITY

Numerous environmental factors affect the susceptibility of crop plants to oxidant injury. It has been shown, for example, that plants well fertilized with nitrogen, are more severely injured than nitrogen deficient plants. Well-watered plants or plants grown at warm, favorable growing temperatures are also more likely to be damaged by a given oxidant exposure than plants grown at low temperatures under some degree of water stress. In other words, those cultural practices which tend to encourage rapid succulent growth tend to produce plants more likely to be injured by oxidants, and growing conditions which result in poor stunted growth produces less subject to smog injury.

OZONE

A third highly active oxidizing compound present in polluted atmospheres, ozone, can also result in serious plant damage under proper conditions. This substance is produced photochemically from nitrogen oxides and hydrocarbons in the atmosphere. The typical symptoms developed from ozone injury are concentrated (at least in the beginning) on the upper surfaces of the older, more mature leaves on the plant. The upper surface of the leaves may become bleached in appearance in some instances, or in others, tiny, discrete, reddish-brown to dark brown punctate spots may appear, again on the upper surface of the leaf. A flecking or stippled effect on the upper surface of the leaf is characteristic, caused by collapse of the upper palisade cells just under the upper epidermis of the leaf.

Brown stipple on the upper surface of grape leaves in the vineyard is attributed to ozone in the atmosphere, as in the upper leaf surface flecking of cigar-wraper tobacco, formerly known as “weather fleck.” With this latter crop in particular, the injury presents a very serious economic problem. Spinach, alfalfa, and small grains are also quite subject to ozone injury when grown near areas of serious air pollution. Sensitive test plants or indicator plants are tomato, tobacco, bean, and spinach. Ozone concentrations in the atmosphere of 0.15 to 0.5 ppm are sufficient to cause damage to the more susceptible crops.

Possible Control Measures to Reduce or Prevent Air Pollution Injury. Commercial flower growers are able to take some preventive actions that may help reduce the damage to their plants from air pollutants. The success to be expected from such measures will be dependent, of course, upon the innate susceptibility of the plant involved, the severity of the pollution problem encountered, and the specific phytotoxicants involved in the specific situation.

In the Los Angeles area where damage has been severe and of long standing occurrence, many of the commercial growing operations have been moved away from the metropolitan area to more rural areas where air pollution sources are not so abundant. In some cases, growers remaining in polluted areas have been forced to change the crops they are growing from susceptible to resistant types. Ageratum, carnations, some chrysanthemum varieties, larkspur, orchids, Kentia palms, pansies, petunias, roses, snapdragons, and zinnias have been determined to be especially susceptible to air pollution injury. Acacia, calendula, China aster, most chrysanthemum varieties, dahlia, forget-me-not, gaillardia, ivy, lobelia, stock, sweet pea, and viola have been classified as more resistant crops.

In some cases prevention of extremely succulent growth helps a great deal in reducing plant injury. If the plant can be supplied with just enough water and sufficient nutrients to produce slow, healthy growth and is grown at relatively low temperatures, the foliage will be somewhat hardened and less subject to air pollutant damage. This means, of course, that it will take longer to produce the crop, and the final quality may not be of the highest, may be the best that can be achieved under very difficult cultural conditions.

Several different groups of chemical compounds have been found that may be applied to the foliage of plants in air polluted areas which offer some protection. Dithiocarbamates (e.g. zineb), captan and some of their derivatives applied so that the stomata bearing surfaces of the leaves were uniformly covered gave quite effective protection in both laboratory and field tests. The degree of protection was related to the concentration of the chemical, and the longevity of the protection afforded depended upon the quantity of air pollutant present in the atmosphere and the total period of exposure. Action of the protectant was local and systemic, and it appeared to be working by simply inactivating the air pollutant gases (in this case ozone or oxidants) at the leaf surface and preventing their actual entry into the leaf.

Other research work has shown that increasing the vitamin C content of plants by treating them with substances such as potassium ascorbate may reduce plant injury from pollutants such as ozone. In this case, it would be expected that the ozone is reacting with the excess quantities of vitamin C in the cell instead of affecting vital enzyme systems controlling cellular metabolism. This treatment apparently has little effect, however, against other air pollutants, so is rather specific in its protective action.

Treatment of ornamental plants with chemical growth retardants has also been reported to cause reduction in symptom expression after exposure to polluted air. Similar effects have also been observed after application of certain anti-transpirants to plants. In both cases, it is postulated that the protective action here is occurring because these chemicals cause partial or complete stomatal closure, and as a result, interfere with the quick and easy entrance of the air pollutant into the interior of the leaf.

For extra high value crops, such as orchids, filtration of the air in the area where they open and mature their flowers is economically feasible. In California, combination air filtering-air conditioning units have been developed for greenhouse use which work very successfully.
Easter Lilies  
(continued from page 2)

Preparation

The preparation for Easter 1980 will start 3 or 4 years previous. At that time the bulb growers on the West coast will note whether the 1980 Easter will be early, mid-, or late season. This information will be used to determine whether to use early, mid-, or late season cultivars. The grower will then select the short, medium, and tall selections of the cultivar and bulb scales will be used for propagation under, of course, sterile conditions. As the final bulb growing season of 1979 approaches, precise weather information will be fed into computers.

Harvest and Storage

The bulbs will be dug and sorted for size and soundness by machines with just a few people as inspectors. The grading and sorting will all be controlled by computers. Biochemical analyses of the bulbs will determine how much vernalization the crop had accumulated. Through analysis of the weather information and the biochemical information by the computer will determine, the exact temperature and length of additional cooling and heating necessary for the 1980 Easter. The bulbs will be vacuum cooled and then sent to the storage facilities. On completion of storage, the bulbs will be sent to the forcer's establishment with specific instructions as to the forcing temperatures, photoperiods, and other cultural details to be used for that specific season.

Forcing

The forcing operation will be completely palletized. Potting machines will pot-up and move the lilies to pallets which will be conveyed to the forcing area. The grower will have already determined the percentage of short, medium and tall cultivars required. The grower will only inspect the equipment; watering, fertilizing, insect and disease control, temperature, and daylength will all be controlled automatically. In the event of a breakdown of a system, such as heating, the information would be reported to the computer which in turn would supply a new schedule to compensate for the loss. Just before Easter the crop would be sold. The pallets would be conveyed to the packing shed, the plants automatically wrapped, boxed, sorted, the bills tabulated and the plants loaded onto the trucks for the consumer market.

“Easter, 1980” may seem too futuristic and perhaps some of it is, but we do envision fewer labor requirements, more and better selections of cultivars, and a better understanding of growth and flowering control.

Fred Horton Retires  
(continued from page 1)

of the room bearing Fred’s name. He also was presented with a book of letters from friends and alumni. These included letters and comments from all over the world.

It is with sadness we lose his wisdom, his enthusiasm for the industry, his inquisitiveness about plant growth. However, it is with happiness we know he will now be able to devote full time to doing the things he wants to do—especially his hobby “Fred’s Hobby Greenhouse.” Most people have hobbies that are quite different from their job; however, Fred as a completely devoted individual, went home every night to his own “Hobby Greenhouse.”

We want to express our appreciation to this man for the truly outstanding contribution he has made not only to the Department of Floriculture and Ornamental Horticulture and Cornell University but also to the Floricultural Industry. We wish him many years of happiness.

Air Pollution  
(continued from page 5)

Activated charcoal is used as the filtering agent and absorbs the damaging air pollutant gases. The units blow treated air into the greenhouse section and maintain a positive pressure in the house, so that any leaks or air flow through opened doors would always be from inside to outside, thus preventing unfiltered, pollutant-containing air from gaining entry into the house.

In the final analysis, all the specific protective measures that can be taken do not provide a completely satisfactory solution to the problem. Community action programs at the local level and legislative programs at state and federal levels are needed to control and reduce the quantities of pollutants discharged into the atmosphere in the first place. Presently, programs are underway which will eventually require the installation of control equipment on all motor vehicles to reduce pollutant emissions. Likewise, most industrial plants that have been sources of pollutants in the past, are now being forced to install collection and purification devices in their stacks to reduce contamination resulting from their activities. Florists need to keep informed regarding the progress of such developments, and to take an active part in community action programs aimed at clearing the air for present and future generations.

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1968 Short Course
October 27, 28, 29, 1968
Ithaca, New York
Mark Your Calendar

Fred Langaas