Florist's and Air Pollution Problems*

Marlin N. Rogers
University of Missouri
Columbia, Missouri

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 visibilty, 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 toxicants were relatively simple substances such as sulfur dioxide, hydrogen floride, 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 sulfite. 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 from some chemical manufacturing process (e.g. polyethylene manufacturing plants), from the normal respiratory processes of many kinds of living plant material, and

(continued on page 4)

*Reprinted from the Ohio State Florists Assn. Bulletin, No. 453, July, 1967

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 action of the endogenous (internal) growth regulating substances within plants. As a result some typical symptoms include growth suppression, abnormal epinastic growth (bending down) of stems and leaves, increase in stem diameter, 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 orient 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 injury. Shattering or shelling of the florets of snapdragons and calceolaris, "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 greenhouse regularly—particularly during the winter heating season, when minimal greenhouse ventilation is being carried out.

FLUORIDES

These are emitted as waste products from smelting, ceramic, glass, and clay manufacturing industries and from aluminum, chemical, and phosphate plants. Gaseous hydrogen 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 margins 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 necessary 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 resistant species may tolerate levels of up to 500 ppm without any apparent injury. Gladiolus (especially light colored varieties) are particularly sensitive to fluoride injury, 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 fumigating 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 reaction (aldehydes and organic acids) produced typical oxidant injury symptoms; therefore it was concluded that the injurious components were transistory intermediate products, possibly ozonides or peroxides. To date, the exact identity of these substances has not yet been determined.

Basically similar results were obtained by treating plants with the photochemical reaction products of nitrogen oxide and olefins—injury corresponding to that caused by naturally occurring oxidants. The product resulting 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 pollutants. 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-

(continued on page 5)

Air Pollution

(continued from page 4)

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-wrapper 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.

(continued on page 6)

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.