UNIVERSITY OF ILLINOIS EXTENSION
College of Agricultural, Consumer and Environmental Sciences

report on
PLANT DISEASE

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PLANT DAMAGE FROM AIR POLLUTION

Figure 1. Ozone injury to petunia plants.

Air pollution damage to vegetation has been recognized for more than 125 years. Air pollutants are a fact of modern life. The best guess is that between 100 and 200 million tons of man-made air pollutants are released each year into the atmosphere in the United States. According to U.S. EPA's "Latest Findings on National Air Quality: 2000 Status and Trends", over 160 million tons of pollution are emitted into the air each year in the United States. As society has become more industrialized, laws regulating air pollution have become more intense. Before 1955 only smoke laws existed. The U.S. Clean Air Amendments of 1967 and 1970 established maximum limits, or standards, for several major air pollutants. Two standards are applied to each pollutant: The **primary** standard, which protects human health, and the **secondary** standard, which protects human welfare–principally plants and human structures.

The clean air legislation also established federal and state environmental protection agencies (EPAs) and pollution control boards to monitor pollutant concentrations and enforce the air quality standards. For example, the Illinois EPA operates monitors for ozone (Figure 1) and sulfur dioxide, the two most common plant-damaging pollutants, in 23 of the state's 102 counties. As a result, aggregate emissions of six principal pollutants tracked nationally have been cut 29 percent since 1970. Despite this progress, ground-level ozone levels in the southern and north central states have actually worsened in the past 10 years.

Plant injury is common near large cities, smelters, refineries, electric power plants, airports, highways, and streets where motor vehicle traffic is heavy: incinerators and refuse dumps, pulp and paper mills, as well as coal-, gas-, and petroleum-burning furnaces. Plant injury also occurs near industries that produce brick, pottery, cement, aluminum, copper, nickel, and iron or steel, as well as zinc, acids, ceramics, glass, phosphate fertilizers, paints and stains, rubber, soaps and detergents, and other chemicals.

Injury from air pollution can be confused with many things–the disease symptoms caused by fungi, bacteria, phytoplasma, viruses, or nematodes; insect and mite damage; genetic disorders; nutritional deficiencies and toxicities; pesticide spray injury; natural senescence; abuse of plants by man; and the

For further information contact an Extension Specialist in Plant Pathology, Department of Crop Sciences, University of Illinois at Urbana-Champaign or your nearest Extension office.

Our thanks to Bruce Paulsrud, Pesticide Applicator Trainer, and Extension Specialist in the Department of Crop Sciences for his assistance in updating this report.

adverse effects of temperature, wind, water, and salinity. In general, the visible injury to plants is of three types: (1) collapse of leaf tissue, with the development of necrotic patterns; (2) yellowing or other color changes; and (3) alterations in growth.

All known pollutants have an effect on plants sensitive to them, even in low concentrations (0.1 to 55 parts per million [ppm] of air). Not all species of plants react the same to the various air pollutants, nor do all cultivars of a plant species react alike when exposed to the same concentration of a particular pollutant.

The signs of air pollutants on plants include: mottled foliage, "burning" at the tips of edges of the leaves, dieback of twigs, growth and yield suppression, early leaf drop, delayed maturity, abortion or early drop of blossoms, plus a reduced quality of fruit and produce.

Plant symptoms caused by air pollutants are expressed as chronic or acute, depending upon the extent of injury. Chronic injury does not usually kill tissue; acute injury kills all or a portion of a leaf or needle. **Acute injury** results from a short- or long-term exposure to high levels of pollution, or when a plant is particularly sensitive to a pollutant. Acute injury is characterized by well-defined areas of dead tissue. Entire leaf or even whole plant death may occur. Affected plants often are dwarfed and readily found in fumigated areas. **Chronic injury** usually results from low levels of pollution that cause slight injury over a long period of time, or if a plant has some resistance to the pollutant. Chronic symptoms are manifested by yellowing, stippling, dwarfing, or growth loss without visible symptoms.

The factors governing the extent of the damage and the regions in which air pollution is a problem are the (1) kind and concentration of the pollutant, (2) distance from the source, (3) length of exposure, and (4) meteorological conditions. Other important factors are city size and location, land topography and air drainage, soil moisture and nutrient supply, maturity of plant tissues, time of year, species and varieties (cultivars) of plants grown, and the like. Extremes of temperature, humidity, and light or a soil-moisture deficit often alter a plant's response to an air pollutant.

The damage caused by air pollution usually is severe during warm, clear, still, humid weather when the barometric pressure is high. Toxicants accumulate near the earth's surface when the warm air aloft traps cooler air at the ground level–a phenomenon called "air inversion."

Plant responses to air pollutants are helpful in:

1. Establishing the early presence of airborne contaminants.

2. Determining the geographical distribution of the pollutants.

3. Estimating the concentration of pollutants.

4. Providing a passive system for collecting pollutants for later chemical analysis.

5. Obtaining direct identification of different air pollutants on the basis of plant species and variety or cultivar injured.

The more important pollutants–ozone, sulfur dioxide, fluorides, chlorine, peroxy-acetyl nitrate or PAN, and ethylene–are considered by their symptoms and the concentrations likely to produce injury; also, listings are provided for certain very sensitive plants, as well as for somewhat resistant ones. Since the lists of sensitive and tolerant or resistant plants are prepared by a number of individuals working in different geographic areas at different times of the year, under a variety of environmental conditions and with numerous cultivars of a species, you should not regard the lists as absolute.

Other air pollutants omitted from this report include various fumes, odors, particulates (solids in smoke and dust), aerosols, salt spray, organic and inorganic acids, ammonia, carbon monoxide, hydrogen sulfide, aldehydes, oxides of nitrogen, tars, manufactured or illuminating gas, and the vapors or spray drift from hormone-type herbicides such as 2,4-D.

INORGANIC POLLUTANTS

Ozone (0_3)

Ozone is the most important, plant-toxic air pollutant in the United States. It is an active form of oxygen that causes a variety of symptoms, including tissue collapse, interveinal necrosis, and markings on the **upper** surface of leaves known as stipple (pigmented yellow, light tan, red brown, dark brown, red, black, or purple), flecking (silver, or bleached straw-white) (Figure 1), mottling, chlorosis or bronzing, bleaching, and a marginal rolling and scorching of leaves on lilac. Growth is stunted. Flowering and bud formation are depressed. Affected leaves of certain plants, such as citrus, grape, and pines, both wither and crop prematurely. Conifers frequently show a mottled green and yellow to brown and tipburn, or a yellow to brown or orange-red flecking, banding, and reddish-brown dieback of the needles. Susceptible white pines range from stunted to dwarfed and chlorotic. The injury pattern in small grains and forage grasses generally occurs as a scattering of small, yellowish or white-to-tan flecks on one or both leaf surfaces. The flecks later may merge to form larger, bleached-white to yellowish dead areas. Ozone usually attacks nearly mature leaves first, progressing to younger and older leaves. Young plants generally are the most sensitive to ozone; mature plants, relatively resistant. Ozone-killed tissues are readily infected by certain fungi (for example, *Botrytis*).

Ozone is brought down from the stratosphere by turbulence in strong vertical down-drafts during severe electrical storms; more important, it is produced when sunlight reacts with nitrogen oxides and hydrocarbons formed by refuse burning and combustion of coal or petroleum fuels, especially the exhaust gases from internal-combustion engines. When oxidant levels in the air are high, more than 90 percent is ozone. These levels usually are at their highest point from around 11 a.m. to 5 p.m. and relatively low at night. Ponderosa pines growing in the San Bernadino Mountains are injured and being killed by ozone which originates 75 miles away in Los Angeles.

Concentration. Exposure of sensitive plants for 4 to 6 hours at levels of 0.02 to 0.04 parts per million (ppm) of air or more will produce injury patterns. Susceptible tobaccos (for example, Bel W-3) are injured–a condition called "weather fleck"–when concentrations of ozone reach or exceed 0.04 ppm. There is a great difference in ozone susceptibility between cultivars of the same plant (for example, bean, grape, maple [red], oats, onion, petunia, pines, potato, privet, spinach, squash, sweet corn, and tobacco). The extent of the injury depends on the plant species and the environmental conditions prior to and during exposure. Ozone and sulfur dioxide often combine to cause plant injury at lower concentrations of these pollutants than either would cause alone.

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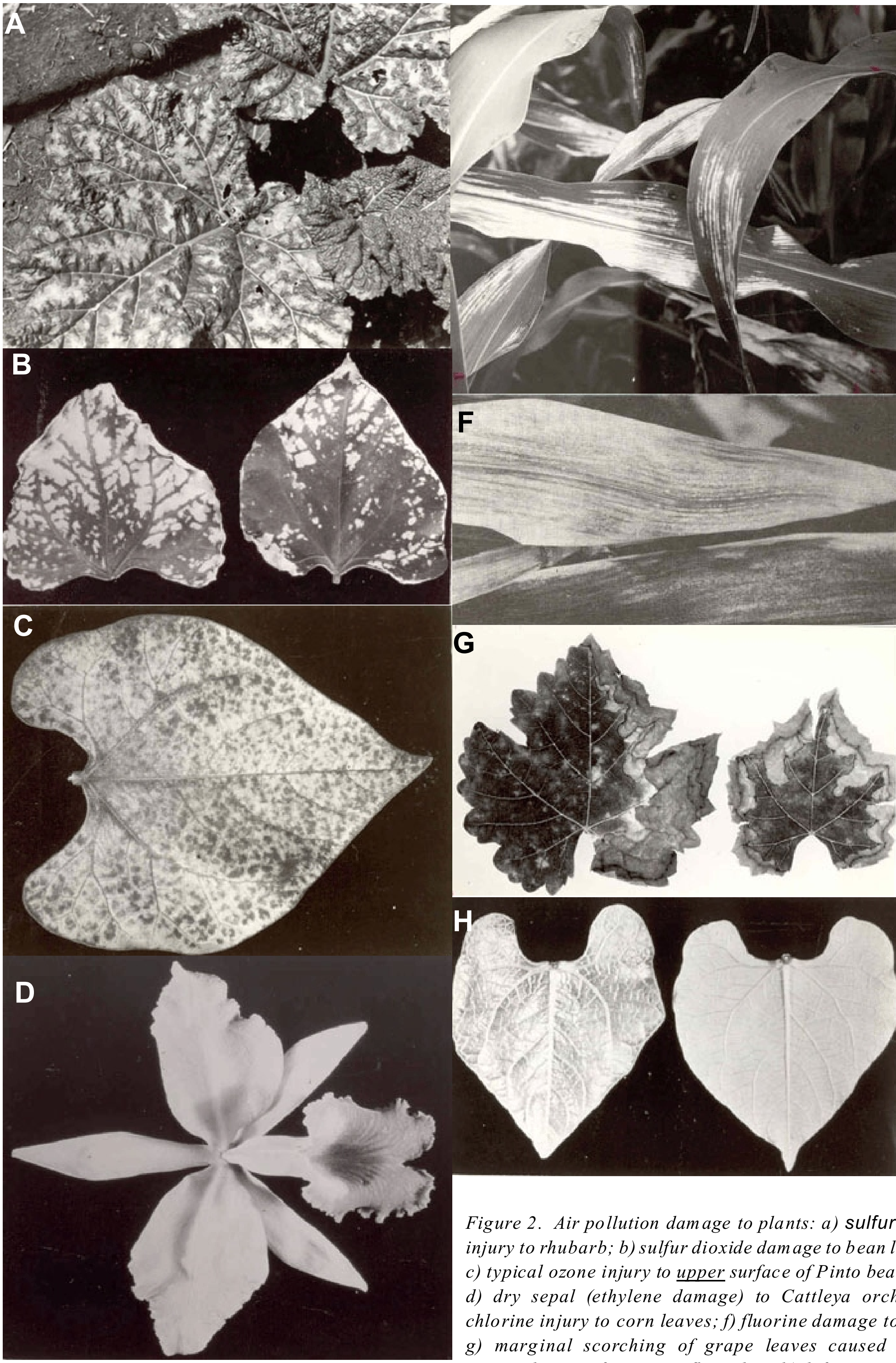

Figure 2. Air pollution damage to plants: a) sulfur *injury to rhubarb; b) sulfur dioxide damage to bean leaves; c) typical ozone injury to upper surface of Pinto bean leaf; d) dry sepal (ethylene damage) to Cattleya orchid; e) chlorine injury to corn leaves; f) fluorine damage to corn; g) marginal scorching of grape leaves caused by an accumulation of gaseous fluorides; h) left, typical PAN damage to lower surface of Pinto bean leaf, and right, normal leaf. (Photos b, c, d, g, and h courtesy of University of California, Riverside).*

Very sensitive plants

- Abutilon
- alder
- alfalfa
- apricot
- ash (green and white)
- aspen (quaking)
- aster
- avocado
- azaleas (most)
- barley
- bean (green and Pinto)
- beet (table and sugar)
- begonia
- bentgrass (creeping)
- birches (most)
- bluegrass (annual)
- boxelder
- bridalwreath
- broccoli
- bromegrass
- browallia
- brussels sprout
- buckwheat
- carnation
- carrot
- catalpa
- celery
- cherry (Bing)
- chicory
- chickweed
- Chinese cabbage
- chrysanthemum
- citrus
- clover (red)
- coleus
- corn (sweet)
- cotoneaster (creeping and rock)
- crabapple
- crabgrass
- dahlia
- dill
- locust
- hypericum
- larches (European and Japanese)
- lilac
- locust (black)
- maples (silver and sugar)
- marigold
- milkweed
- mint
- mimosa
- mountain ash (European)
- muskmelon
- oaks (gambel, pin, scarlet, and white)
- oats
- onion
- orchardgrass
- parsley
- parsnip
- pea
- peach
- peanut
- petunia
- pines (Austrian, Coulter, Dwarf mugo, jack, Jeffrey, Monterey, pitch, ponderosa, scotch, Torrey, Virginia, and eastern white)
- poplar (hybrid)
- potato
- privets (some)
- pumpkin
- radish
- redbud (American)
- redwood
- rye
- safflower
- salvia
- scallion
- sequoia
- smartweed
- snowberry
- soybean
- spinach
- squash
- strawberry
- sumac
- sweet gum
- sweet potato
- Swiss chard
- sycamore
- tobacco
- tomato
- tree-of-heaven
- tulip tree
- turnip
- verbena
- walnut
- wheat
- willow (weeping)

Somewhat resistant plants

- Andromeda (*Pieris*)
- arboritae
- avocado
- birch (European white)
- boxwood
- cotton
- cucumber
- descuraina
- dogwoods (gray and white)
- Douglas fir
- euonymus (dwarfed winged)
- firs (balsam and white)
- firethorn
- geranium,
- gladiolus
- gloxinia
- gum (black or sour)
- holly
- impatiens
- ivy (English)
- Jerusalem cherry
- junipers (Pfitzer and western)
- kalanchoe
- lambsquarters
- lettuce (garden)
- lindens (American and littleleaf)
- locust (black)
- maples (most)
- pagoda tree (Japanese)
- pear
- pepper
- periwinkle
- piggy-back plant
- pines (digger, red, single-leaf pinon)
- poinsettia
- rhododendrons (some)
- snapdragon
- spirea
- tolmiea
- viburnums (most)
- Virginia creeper
- walnuts (black and English)
- wheat
- yew

Sulfur Dioxide ($S0_2$)

The exposure of succulent, broadleaved plants to SO_2 (and its byproduct, sulfuric acid) usually results in dry, papery blotches that are generally white to tan or straw-colored and marginal or interveinal (Figures 2a and 2b). On some species, chronic injury results in brown to reddish-brown or black interveinal blotches. Both the upper and lower leaf surfaces are affected. The leaf veins normally remain green. Chlorosis (yellowing) and a gradual bleaching of the surrounding tissues is fairly common. Injured grass blades develop light tan to white streaks on either side of the midvein. A tan to reddish-brown dieback or banding occurs on conifer leaves, with adjacent chlorotic areas. Growth suppression, reduction in yield, and heavy, premature defoliation may also occur. Full-grown and nearly full-grown leaves and young plants are most susceptible to SO_2. Young and old leaves are usually less sensitive.

Concentration. The degree of injury increases as **both** the concentration of sulfur dioxide and/or the length of exposure increases. Sensitive plants are injured by exposures as low as 0.5 parts per million (ppm) for 4 hours, or 0.25 ppm for 8 to 24 hours. Plants are most sensitive to SO_2 during periods of bright sun, high relative humidity, and adequate plant moisture during late spring and early summer when plants are making the most rapid growth.

<u>Very sensitive plants</u>

Alder
alfalfa
amaranthus (careless weed)
apple
apricot
ashes (green and white)
aspens (quaking and large-toothed)
aster
bachelor's button
barley
beans (broad and green)
beech
beets (table and sugar)
begonia
bindweed
birch (white)
blackberry
bluegrass (annual)
broccoli
bromegrass
brussels sprout
buckwheat
carrot
catalpa
centaurea
cheatgrass
chickweed
China aster
clovers (red and yellow sweet)
columbine
cosmos
cotton
crabapple
curly dock
dahlia
dandelion
Douglas fir
eggplant
elm (American)
endive
fern (bracken)
fir (white)
fleabane
forsythia
four o'clock
geranium (wild)
gladiolus
hawthorn (scarlet)
hazel
hemlock
kohlrabi
larch
lettuce (garden and prickly)
mallow
morning glory
mountain ash (European)
mulberry
mustard
nightshade (black)
oats
okra
orchardgrass
Pacific ninebark
pea (garden)
peach
pear
pecan
peppers (bell and chili)
pepper-tree (Brazilian)
petunia
pines (Austrian, jack, loblolly, ponderosa, red, Virginia, and eastern white)
plantains
polygonum
poplar (Lombardy)
pumpkin
quince
radish
ragweed
raspberry
rhubarb
rockspirea
spruce (Engelmann)
squash
strawberry
sumac
sunflower
sweet pea
sweet potato
sweet William
Swiss chard
tomato
tulip
tulip tree
turnip
velvetweed
verbena
violet
walnut (English)
wheat
willow
zinnia

Somewhat resistant plants

Arboritae	cucumber	juniper	potato
boxelder	dogwood	lilac	privet
cabbage	ginkgo	linden	purslane
canna	gourds	maple	rose
castor bean	gum (black or sour)	milkweed	shepherd's purse
cedar	hibiscus	mock orange	snowball
celery	holly	muskmelon	sorghum
cherry (sweet)	honeysuckle	oaks (most)	sourwood
chrysanthemum	hornbeam	nightshade	spruce (white)
citrus	horseradish	onion	viburnum
corn	iris	pine (mugo)	Virginia creeper
cottonwood	Johnsongrass	planetree	wisteria

Fluorides (F)

The typical injury by gaseous (primarily hydrogen fluoride (HF) and silicon tetrafluoride (SiF_4) or particulate fluorides is a yellowish mottle to a wavy, reddish-brown or tan "scorching" at the leaf margins and tips of broadleaved plants, and a "tipburn" of grasses and conifers (Figures 2f and 2g). A narrow, chlorotic to dark-brown band often occurs between living and dead tissue. Citrus, poplar, sweet cherry, and corn foliage exhibit a chlorotic mottling, streaking, or blotching prior to the development of the typical "burned" area. Leaves and fruits, such as apple, apricot, citrus, fig, peach, plum, and prune, may fall prematurely. Injured areas in stone-fruit leaves may become brittle and drop out, leaving shot-holes. The young, succulent growth is most easily injured. Fruits may soften or become necrotic at the blossom end. Fluoride-contaminated forage that is eaten by cattle or sheep may cause fluorosis.

Fluorides (compounds containing the element fluorine) are produced by combustion of coal and by glass, aluminum, steel, pottery, brick, and tile, as well as ferro-enamel, cement, fiberglass, and ceramic industries. They are also produced by refineries, metal ore smelters, and phosphate fertilizer factories. Recently installed efficient controls in these industries have reduced fluoride output. Localized problems still exist where controls are lax.

Concentration. Accumulated leaf-fluoride concentrations of 10 to 150 ppm often result in injury to sensitive plants, although resistant cultivars and species of plants will tolerate leaf concentrations of 500 to 4000 ppm or more without visible injury. A 4-week exposure of susceptible gladiolus to an air concentration of 0.0001 ppm, or less than 24 hours at 10 parts per billion (ppb), produced leaf concentrations of 150 ppm and definite tissue necrosis. There is a wide variation among cultivars or clones of the same plant in their susceptibility to fluorides: for example, apricot, begonia, corn, gladiolus, grape, peach, ponderosa and white pines, roses, and sweet potato. The extent of tissue damage is related to the dosage and the quantity of accumulated fluoride.

Very sensitive plants

Alfalfa
apple
apricots (Chinese, flowering, Royal, and Tilton)
azalea
barley
blueberry
boxelder
buckwheat
canna
cattail
cherry
chickweed
citrus
corn
crabgrass
Douglas fir
gladiolus
grape (European)
hypericum
iris
Jerusalem cherry
Johnsongrass
lambsquarters
larch (western)
mahonia (creeping)
maple
mulberry
nettleleaf
goosefoot
oaks (some)
oxalis
paulownia
peach
peony
pines (most)
plum (Bradshaw)
poplar
prune (Italian)
St. John's-wort
smartweed
sorghum
spruces (blue, Colorado blue, and white)
sweet potato
sycamore
tulip

Somewhat resistant plants

Alder (European black)
arborvitae
ashes (European and Modesto)
asparagus
bean (green)
birches (cutleaf and European white)
bridalwreath
burdock
cabbage
camellia
Canterbury bell
carrot
columbine
cotton
cucumber
currant
dandelion
dock
dogwood
eggplant
elderberry
(European)
elms (American and Siberian)
fir (grand)
galinsoga
hemlock
junipers (most)
laurel
lettuce (Romaine)
lindens (American and littleleaf)
lobelia
locust (black)
marigold
mock orange
mountain ash (European)
mountain laurel
nightshade (black)
onion
orchardgrass
parsnip
pea (garden)
pear
peppers ((bell and chili)
petunia
pigweed
planetree (London)
plantain
plum (flowering)
poplar (balsam)
potato privet
purslane
pyracantha
ragweed
raspberry (red)
rhododendron
rose
Russian olive
smartweed
snapdragon
soybean
spinach
spruces (Engelmann and white)
squash
strawberry
sugar cane
sweet gum
sweet pea
sycamore
tobacco
tomato
tree-of-heaven
Virginia creeper
willows (several)
wheat
zinnia

Chlorine (Cl_2)

Chlorine injury is somewhat similar to that caused by sulfur dioxide and fluorides, in that it is marginal and interveinal. Two types of damage generally can occur: (1) with broadleaved plants, necrotic, bleached, or tan-to-brown areas that tend to be near the leaf margins, tips, and between the principal veins; and (2) with grasses, progressive streaking toward the main vein in the region between the tip and the point where the grass blade bends, usually occurring alongside the veins (Figure 2e). Middle-aged leaves or older ones are usually more susceptible than the young ones. Bleaching without killing can occur, as well as tissue collapse. Conifers may show tipburn on the current season's needles.

Hydrogen chloride (HC_1) and chlorine ($C1_2$) are emitted from the stacks of glass-making factories and refineries. These gasses are also produced by incineration, rocket exhaust, scrap-burning, burning of polyvinylchloride plastics, and as the result of spillage, such as from chlorine storage tanks. Chlorine-injured vegetation often is observed near swimming pools, water-purification plants, and sewage-disposal facilities.

Concentration. Very susceptible plants show symptoms when exposed for 2 hours or more at concentrations of chlorine ranging from 0.1 to 4.67 ppm. Chlorides do **not** accumulate in plant tissues after exposure to chlorine.

Very sensitive plants

Alfalfa	bridalwreath	gomphrena	sweetgum
amaranthus	buckwheat	grape	tobacco
apple	catbrier	honeysickle	tomato
ash	cherry	horse chestnut	tree-of-heaven
azalea	chickweed	hydrangea	tulip
barberry	chokecherry	Johnsongrass	venus looking glass
basswood	coleus	Johnny-jump-up	violet
beans (Pinto and	corn (sweet)	juniper	Virginia creeper
Scotia)	cosmos	larch	wandering Jew
birch (gray)	crabapple	lilac	witch hazel
blackberry	cucumber	mallow	zinnia
bluegrass (annual)	dandelion	maple (Norway)	
boxelder	dogwood	sunflower	

Somewhat resistant plants

Arborvitae	eggplant	maple (Japanese)	pine (Austrian)
begonia	fir (balsam)	mignonette	polygonum
bluegrass (Kentucky)	geranium (wild)	myrtle	Russian olive
cacti	hemlock	oak (red)	rye
chrysanthemum	holly (Chinese)	oxalis	soybean
corn (field)	iris	pear	tobacco
cowpea	ivy (Boston)	pepper (black)	yew
daylily	lambsquarters	pigweed	

ORGANIC POLLUTANTS

Peroxyacetyl Nitrate (PAN)

The most important, plant-toxic oxidant, next to ozone, is PAN[1]. It is formed by oxides of nitrogen reacting with unsaturated hydrocarbons (simple olefins) in the presence of light. Like ozone, PAN is produced when sunlight reacts with various exhaust gases from motor vehicles and industries. PAN causes a collapse of tissue on the **lower** leaf surface of numerous plants. The typical leaf marking is a

[1]other PANs, such as peroxypropionyl nitrate and peroxybutyryl nitrate, may also be present in urban air and may produce symptoms that are indistinguishable from those caused by peroxyacetyl nitrate.

glazing, bronzing, or silvering that commonly develops in bands or blotches (Figure 2h). On some plants, such as petunia, Pinto bean, tomato, and tobacco, the collapse may be through the entire thickness of the leaf blades. In grasses, the collapsed tissue has a bleached appearance, with tan-to-yellow, transverse bands. Conifer needles turn yellow. Early maturity or senescence, chlorosis, moderate to severe stunting, and premature leaf drop may also occur. PAN is most toxic to small plants and young leaves. The very young and most mature leaves are highly resistant.

Concentration. Typical damage to susceptible plants occurs with PAN at levels of 0.01 to 0.05 ppm for an hour or more. Plant injury requires light before, during, and after exposure. Injury is increased by any factor contributing to maximum plant growth. PAN is best known in the Los Angeles basin area, with injury occurring on vegetation from Seattle to San Diego. Little is known about the concentration of PAN in the Midwest or the eastern United States, although it has been reported on a few plants. PAN is unstable, particularly at temperatures above 90°F (32°C).

Very sensitive plants

African violet	dandelion	mint	poinsettia
alfalfa	dill	muskmelon	potato
aster	endive	mustard	primrose
bean (Pinto)	escarole	nettle (little-leaf)	rose
beets (table and sugar)	fennel	oats	salvia
bluegrass (annual)	fuchsia	orchids (some)	snapdragon
carnation	Jimsonweed	pepper	spinach
celery	larkspur	petunia	sunflower
cherry (ground)	lettuce (romaine)	pigweed (rough)	sweet basil
chickweed	lilac	pines (Coulter, Jeffrey, Monterey, and ponderosa)	Swiss chard
clover	linden (littleleaf)		tobacco
dahlia	mimulus		tomato

Somewhat resistant plants

Anthurium	cabbage	honeylocust	poplar (hybrid)
apple	cacti	ivy (English)	radish
arborvitae	calendula	larches (European and Japanese)	redwood
ashes (green and white)	camellia	maple	rhubarb
azalea	cauliflower	mountain ash (European)	rye
basswood	coleus	narcissus	sequoia
bean (lima)	corn	oaks (most)	sorghum
begonia	cotton	onion	spruce
birch (European white)	cucumber	pansy	strawberry
broccoli	cyclamen	periwinkle	sweet gum
bromelia	dogwood	pines (Austrian, eastern white, pitch, red, Scotch, and Virginia)	touch-me-not
buckwheat	Douglas fir		tulips
buttercup	firs (balsam and white)		wheat
	hemlock (eastern)		

Ethylene ($H_2C\text{-}CH_2$)

Damage is often associated with PAN and ozone in urban areas, since ethylene is one of the many products of auto, truck, and bus exhaust. Ethylene also results from the manufacture of illuminating gas; incomplete combustion of coal, gas, and oil for heating; refuse burning; petroleum refining; and is a by-product of polyethylene manufacture. Ethylene modifies the activities of plant hormones and growth regulators, affecting developing tissues and normal organ development without causing leaf-tissue collapse and necrosis. Injury to broadleaved plants occurs as a bud abscission, downward curling of the leaves and shoots (epinasty), followed by a stunting of growth. Ethylene also causes dry sepal in *Cattleya, Phlaenopsis*, and other orchids (Figure 2d); "sleepiness" (an inward petal-curling and failure of buds to open) in carnation, narcissus, and rose; color-breaking and blasted buds in roses; and the shelling (early drop) of azalea, snapdragon, stock, larkspur, and calceolaria blooms. The more resistant, broadleaved plants and grasses may only be stunted. Conifers drop their needles and young cones. New needle growth is stunted, and cone development is poor. Similar symptoms are provided by other unsaturated hydrocarbons such as acetylene and propylene.

Ethylene is a problem in fruit, vegetable, and cut-flower storage rooms and greenhouses where manufactured gas is still used.

Concentration. Air concentrations of 0.001 ppm for 24 hours will cause the sepals of orchid flowers to turn brown or wither and die. An exposure of 0.1 ppm for 6 hours will cause epinasty in tomato or pepper and sleepiness in carnation. The extent of injury depends on the air temperature, plant species, and age of the organ, as well as on the ethylene concentration.

Very sensitive plants

Azalea	cowpea	orchids (some)	snapdragon
bean (Black Valentine)	cucumber	pea	stock
blackberry	larkspur	peach	sunflower
buckwheat	lilac	pepper	sweet pea
calceolaria	lilies (Easter and Regal)	philodendron	sweet potato
carnation	marigold (African)	potato	tomato
cotton	narcissus	privet	tulip
		rose	

Somewhat resistant plants

Acacia	clover	forget-me-not	radish
aster (China)	corn	lettuce (garden)	ryegrass
beet	dahlia	oats	sorghum
cabbage	endive	onion	violet
calendula			

CONTROL

The solution to the air pollution problem is complex and involves:

1. Enforced use of special, adjusted control devices on motor vehicles and aircraft.

2. Stopping emissions at the source (the smoke stack or combustion chamber) by such "scrubbing systems" as electrostatic precipitators, filtering devices including fabric filters, absorption equipment, gravity settling chambers, sonic and ultrasonic collectors, and byproduct recovery.

3. Public awareness and adequate enforcement of federal, state, and local legislation.

4. Plant breeding and selection of less susceptible crops for critical areas.

5. Using less susceptible plants or cultivars.

6. Carbon filtration of the air in greenhouses.