photochemical oxidants on white bean, tomato and tobacco crops throughout southwestern Ontario; salt spray on roadside peach and apple orchards; cement dust on apple orchards; soot on corn fields; fluoride and boron, nickel and cobalt, and ammonia.

Recent air pollution episodes

A number of air pollution episodes resulting in major effects have occurred in recent years in southwestern Ontario. On August 27, 1973, a major soot fallout incident occurred in Windsor. During the early morning hours of August 27 an operational problem was experienced at the River Rouge Plant of the Detroit Edison Company situated immediately downstream from Zug Island on the United States side of the Detroit River. The resulting faulty combustion lead to the emission of substantial quantities of soot which, under the influence of generally southwesterly winds, settled out over major portions of Windsor, Belle Isle, and the east Detroit community of Grosse Pointe. Ninety-nine complaints were received and investigated by the Ontario Ministry of the Environment. In most cases the soot had entered homes through open doorways or windows and caused considerable soiling of clothing, walls, floors, and furniture.

With respect to vegetation it was found that the soot consistently deposited on the plant surfaces exposed to the southwest. In the zones of heaviest deposition, exposed plant surfaces accumulated more soot than smooth surfaces. Consequently, foliage on tree species such as silver poplar, sumac and elm were more heavily covered than smoother foliage on eastern cottonwood and lilac.

In another major episode in the Windsor area, a number of complaints were received in late June 1972 concerning severe salt damage to trees and gladioli in the vicinity of the Canadian Rock Salt Co. at La Salle. Severe injury to vegetation was observed to extend for about 3/4 mile southeast of the salt mine and an area of light injury extended a further 1/2 mile south. The injury zone was about 1/3 mile in width. No injury was found north of the salt mine, since the episode occurred as a result of exceptionally strong winds which blew from the north–northwest on the evening of June 20 to the morning of June 21 in 1972.

In the severe zone of injury almost all plant species displayed various degrees of injury, which was predominantly a marginal necrosis of the leaves, with the necrotic areas turning dark and becoming brittle. Injury occurred equally on grasses and weeds at ground level to heights of 40 to 50 feet on trees. In all cases, the injuries were more severe on the sides of the trees and shrubs facing the salt mine. In the zone of light injury, the following species appeared to be most sensitive and were used to map the extent of injury in the area: Manitoba maple, sumac, wild grape, elderberry, red mulberry, cottonwood, and peach.

Samples of injured vegetation and uninjured control samples were collected for chemical analyses. The results showed that injured vegetation contained from 2 to 10 times the amount of sodium and chloride contained in uninjured samples. Foliage collected from the sides of trees facing the salt mine contained 2 to 3 times the amount of salt in foliage collected from the opposite sides of the trees.

Other major episodes

Also in 1972, two other major episodes occurred in southwestern Ontario which resulted in substantial effects on vegetation. These two episodes occurred near Sombra in late June and early September in 1972. In both cases the Detroit Edison power plant near St. Clair was responsible, and in one case emissions of high concentrations of sulphur dioxide caused the injuries and in the other case a heavy soot emission caused extensive effects.

In late June 1972, complaints were received from 10 cottage owners on the Ontario side of the St. Clair River regarding the sudden occurrence of severe injuries on vegetation. An investigation was conducted by the Phytotoxicology Section and SO_2 injury was found in an area of about 1 mile wide and 3½ miles long extending south-south-east of the St. Clair River. Sulphur dioxide was diagnosed as the cause based on the appearance of the injuries and on the sensitivity and resistance of plant species. Almost every plant species in the severe injury zone had symptoms of acute SO_2 injury. In the area of less severe injury only sensitive plants were affected by SO_2 (raspberry, white ash, willow, apple, cottonwood, manitoba maple, scotch pine, white pine and white birch). Vegetation samples collected from the severe injury zone contained 1.6 to 2.2 times the amount of sulphur contained in similar samples collected from a control area. The shape of the injury zones, the absence of similar injury symptoms downwind from other industries in the area, and the direction of the winds during the fumigations showed that the source of the SO_2 was from Detroit Edison's St. Clair plant.

Surveys are also conducted throughout southwestern Ontario on the occurrence and incidence of photochemical oxidant damage to farm crops. In 1972 and 1973 widespread ozone injury to white bean crops and peroxyacetyl nitrate (PAN) – type injury to tomato crops were recorded. In 1973 an area of approximately one million acres in southwestern Ontario displayed evidence of moderate to severe oxidant bronzing on surveyed white bean crops. PAN-type injury was detected in 1972 throughout the major tomato production areas near Chatham, Dresden and Leamington. In 1973 two distinct injury areas were detected; one similar to the area affected in 1972 and the other to the east near Simcoe and throughout the Niagara peninsula. It is considered that these are the first documented observations of PAN-type symptoms on vegetation in Canada.

MONITORING, DETECTING, AND EFFECTS OF AIR POLLUTANTS ON HORTICULTURAL CROPS: SENSITIVITY OF GENERA AND SPECIES

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Air pollutants influence the growth, yield and quality of many horticultural crops. It is difficult to determine and evaluate the impact of air pollution on the horticulture industry for the following reasons: The variable environments in which horticultural crops are grown markedly influence the amount of foliar injury caused by air pollutants. The large number of cultivars within horticultural crop species contribute to the magnitude of understanding necessary to evaluate pollutant effects. Genetic, morphological and physiological differences among species and cultivars within species also influence foliar injury and plant sensitivity. The amount of economic loss in horticultural crops due to air pollutants varies from year to year. This variation is probably most directly related to daily and seasonal variations in ambient concentrations of air pollutants. Horticultural crops may be subjected to high pollutant concentrations at different stages of plant maturity. These different stages of growth and development may be differentially affected by pollutant concentration and thus influence yield. Past estimates of crop yield losses have been based primarily on assessment of visual injury. Presently, there is a lack of suitable methodology to assess air pollution impacts under field conditions. Open-top chambers (40, 60) are an improvement but better techniques are needed. Finally, air pollution research is published in a variety of scientific journals and some of these references may not come to the attention of horticultural scientists,

Air pollution is a rural, as well as an urban, problem. Ozone (O_3) concentrations in the summer frequently reach 10-20 pphm along the eastern seacoast and several hundred miles inland from Boston to the Carolinas. Similar concentrations occur throughout the central United States at distances of 100 miles or more from major metropolitan areas. Rural areas are now experiencing effects of sulfur dioxide (SO_2) emanating from combustible fuel sources used to generate electricity. These power plants may increase the ground-level concentrations of SO_2 and the amount of acid mist or acid precipitation, which is a concern in the United States and elsewhere (59).

Recent reviews of air pollution impacts on vegetation have included protection of horticultural plants (72), physiological and biochemical aspects of injury (25), growth and yield loss due to chronic exposures (28), environmental influences on plant injury (41), interactions between pollutants and plant parasites (38), use of plants as indicators of pollution (77), recognition of air pollution injury (54) influences of air pollution on crop production (42), research needs on herbaceous and ornamental plants (44), and the

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responses of plants to combinations of pollutants (78). Although pollution effects on some species of horticultural crops have been studied in detail, others have been essentially ignored. Much more information on yield losses is needed on all horticultural crops.

My purpose in this review is as follows: 1) identify the major gaseous pollutants that effect horticultural crops; 2) discuss, briefly, the sensitivity of various species and cultivars; 3) identify and tabularize some of the more important information concerning air pollutant effects on plant growth and yield; and 4) discuss some specific research needs. This information will provide a data base for evaluation by both research and extension horticulturists.

Major gaseous pollutants

Air pollutants of major concern may be listed in order of their importance as follows: 1) O_3 and other photochemical oxidants, such as peroxyacetyl nitrate (PAN); 2) SO_2, 3) oxides of nitrogen (NO_2 and NO); 4) ethylene; and 5) gaseous fluoride (HF). Each of these pollutants other than the first category are directly produced during combustion of fossil fuels or as by-products of smelting and other industrial processes. Photochemical oxidants, primarily O_3, are not produced from fuel combustion, but result from the action of ultraviolet light and oxygen on hydrocarbon and oxides of nitrogen released into the atmosphere during combustion processes. Ozone is produced as follows:

$$1)\quad NO_2 \xrightarrow[\text{light}]{\text{U.V.}} NO + O$$

$$2)\quad O + O_2 + M \longrightarrow O_3 + M$$

$$3)\quad O_3 + NO \rightleftharpoons NO_2 + O$$

$$NO_2 + O \rightleftharpoons NO + O_3$$

When hydrocarbons are present in the air, they are oxidized; this oxidation converts the NO to NO_2, thus permitting ozone to accumulate. The M represents an energy absorber that functions as a collisional molecule leading to the formation of a stable molecule of O_3 (97).

Ozone concentrations of 5 to 12 pphm for 2- to 4-hour exposure periods will cause injury to the most sensitive horticultural crops. Background concentrations of ozone in rural areas of the eastern United States are approaching 5 pphm throughout the growing season and in urban areas, may be still higher. Only a few parts per billion of PAN, another of the photochemical oxidants, may cause foliar injury to certain horticultural crops.

Sulfur dioxide can injure sensitive plant species at concentrations of 25-50 pphm for 8 hours. Sulfur dioxide may also interact with ozone or NO_2 to produce foliar injury which is greater than the additive injury of each gas singly. For example, mixtures of SO_2 and NO_2 injure vegetable crops such as bean and tomato at concentrations of 10–25 pphm of each pollutant during a 4-hour exposure period (Table 1). Nitrogen dioxide is the least phytotoxic of the major air pollutants, but growth of certain crops such as tomato and citrus is suppressed during continued exposure to low concentrations of NO_2 (86, 88, 90).

Ethylene decreases the growth and productivity of 'Pinto' beans and other crops during continuous exposure as low as 25 ppb (1). Fluoride also seriously affects crop plants, but the impacts are limited to areas around aluminum and glass manufacturing plants. Fluoride may accumulate in plant tissues and seriously affects animals and humans that ingest exposed plants used for food.

Table 1. Influence of various mixtures of nitrogen dioxide and sulfur dioxide on foliar injury.[z]

Concn (pphm)		Exposure duration	Foliar injury[y]		
NO_2	SO_2	(hr)	Pinto bean	Radish	Tomato
10	10	4	11	27	1
15	10	4	24	24	17
15	25	4	4	4	0
20	20	4	16	6	0

[z]Foliar injury resulting from 4 hr exposure to NO_2 and SO_2 singly would occur at approx 200 and 50 pphm, respectively. Data from Tingey, D. T. et al. 1971. *Phytopathology* 61:1506-1511.

[y]Avg % leaf injury of the 3 most severely injured leaves/plant except for bean, for which injury on only the 2 primary leaves was considered.

Species and cultivar sensitivity

Lists of horticulture crops that are susceptible or resistant to each of the five major air pollutants are difficult to prepare. Similar studies may show contradictory results because: 1) environmental conditions before and during exposure may have differed, 2) different cultivars may have been used: 3) the plants may have been exposed at different stages of maturation and; 4) pollutant concentrations and exposure duration may not have been well defined. Nevertheless, some reliable lists of relative sensitivity developed on the basis of foliar injury from the major gaseous pollutants are available (54, 83, 84). These lists need to be interpreted carefully, but they can be useful to both research and extension horticulturalists.

Some general observations may be made about the foliar sensitivity of horticultural crops species to pollutants. Tree and certain small fruits have been reported sensitive to SO_2 (34, 35). Many native tree species have been evaluated near SO_2 sources in the U.S., Canada and Europe. Little information is available on pollutant effects on ornamental and nursery crops although some limited species screening has been done with O_3 and SO_2 (98, 99). Most vegetable and certain floricultural crops are visibly injured by ozone, where oxidant levels often exceed 15 pphm during the growing season. Richards et al. (82) identified grape stipple as the first plant disease caused by ozone.

Cultivar sensitivity has been a primary theme of numerous research articles. These studies have involved both greenhouse evaluations and determinations under ambient oxidant conditions. The number of different cultivars tested for each pollutant are presented for vegetable and fruit crops (Table 2) and floriculture and ornamental crops (Table 3). Among vegetable crops tomato, potato, and bean cultivars have received the greatest attention, with more than 300 tomato cultivars evaluated for sensitivity to ozone. Cultivars of floriculture crops, such as petunia and gladiolus, have been extensively evaluated. However, few studies emphasizing cultivar sensitivity to NO_2 PAN, and HF exist. Gladiolus is a sensitive indicator of HF and many cultivars have been evaluated.

Nearly all the studies of crop species contain cultivars both susceptible and resistant to each pollutant. Some cultivars may be sensitive to each of the five major pollutants, while others are sensitive to only one. Some horticultural crops are not visibly injured by pollutants, but show decreased growth, delay in flowering, or decrease in flower and fruit size and number. Certain cultivars may display visible injury and be classified as sensitive and yet, if little change in yield and marketable quality is identified, be considered tolerant.

The range of foliar injury as a measure of sensitivity among cultivars within species may vary considerably. This is readily

Table 2. Numbers of different vegetable and fruit cultivars tested for sensitivity to various air pollutants.

Vegetable or fruit crop	No. of cultivars tested			Reference
	Pollutants[z]			
	Ozone	SO_2	Ambient air	
Bean	60[y]			24, 48, 50 52,76
Blueberry		4		11
Cucumber	4			73
Grape	16		143	56, 82
Lettuce	8			80
Onion	4			73
Pea	3			71
Potato	37		75	6, 10, 31 45, 50, 51 66, 73, 81
Radish	9			3, 80
Spinach	11			48, 63
Sweet Corn[x]	2		>50[w]	15, 16, 31, 55
Tomato	>338[v]			19, 20, 33, 79

[z]Many vegetable crops have been evaluated for their sensitivity to ethylene (43).

[x]There are no known cultivar evaluations of other vegetable and fruit crops involving NO_2 and HF except for 7 cultivars of citrus exposed to HF (12). Fourteen cultivars of sweet corn have also been evaluated for sensitivity to HF (49).

[y]Each value represents the no. of cultivars tested with each of the pollutants listed.

[w]Various inbred lines of sweet corn were evaluated in the field (15) but the total number and cultivar name was not given.

[v]A series of 1,209 accessions was screened representing collections from 50 countries (20): however, only 24 accessions were reported.

Table 3. Number of different flower and ornamental cultivars and species tested for sensitivity to air pollutants.

Flower, turf, or ornamental crop	No. of cultivars tested						
	Pollutants[z]						
	Ozone	NO_2	PAN	SO_2	HF	Ambient air	Reference
Begonia	17[y]			17			2, 57
Bentgrass	7						7
Chrysanthemum	16		8	16		19	8, 9, 100
Coleus	2			2			2
Coniferious tree sp.	18						23
Gladiolus					118		47, 67
Kentucky bluegrass	5						96
Marigold	2			2			2
Petunia	69	15	6	17		15	2, 17, 30 37, 58
Poinsettia	15			6		2	18, 46, 58 64, 65
Rose					14		14
Safflower	12						53
Shade tree sp.	9						94
Snapdragon	3			3			2
Tulip					2		85
Turfgrass sp.	11			11			7

[z]Many floriculture crops have been evaluated for their sensitivity to ethylene (43).

[y]Each value represents the no. of cultivars tested with each of the pollutants listed.

apparent in tomato and radish (Table 4). The range of percent foliar injury for tomato varies from 10-61%. However, for radish the range is only 17-35%. The relative sensitivity in a group of cultivars exposed to one pollutant may also differ when the same cultivars are exposed to other pollutants (30).

Growth and yield response to pollutants

Foliar injury has been extensively evaluated as conspicuous evidence of species and cultivar sensitivity to ozone and other air pollutants. However, it may not be a good index of growth and development changes affecting yield. For this reason more directly relevant types of measurements are needed and may cause a re-evaluation of earlier ideas on sensitivity of various cultivars to particular pollutants.

Table 4. Variation in sensitivity of selected tomato and radish cultivars exposed to ozone concentrations of 40 pphm and 35 pphm for 1½ hours, respectively.

Ranking	Tomato	% injury[z]	Radish	% Injury[z]
1	Roma VF	61	Cherry Bell	35
2	Red Cherry	47	Crimson Grant	34
3	VF 145B-7879	36	Comet	32
4	Pearson	35	Champion	31
5	Marglobe	33	Red Boy	25
6	Ohio WR-25	30	Calvalrondo	24
7	Heinz 1350	26	Early Scarlet Globe	24
8	Ohio WR-7	24	French Breakfast	23
9	Manapal	23	Icicle	17
10	VF13L	17		
11	VF145B	14		
12	Heinz 1439	10		

Avg injury of three most severely injured leaves based on an average of 27 plants (79, 80).

Plant scientists have begun to investigate such biologically relevant questions as: 1) Do air pollutants affect growth of leaves, stems and roots? and 2) At what concentration does plant growth become limiting? Others are asking such economically relevant questions as: 1) How do pollutants affect the yield and market quality of crops? or 2) What cultivars should be grown in areas of high ambient pollution concentrations? As shown in Tables 5 and 6, more information is available for the biological than for the economic questions. In part this may be a consequence of limited research budgets for evaluating crop losses, the need to develop a detailed understanding of the specific pollutant effects before designing large-scale field studies, or the result of insufficient methodology to research the economic loss questions. In any case Tables 5 and 6 serve to identify specific studies which can be referred to for further evaluation of the biological questions and perhaps some current assessment of economic impacts. Many of the studies cited concern a single susceptible cultivar. It is apparent that, in the future, cultivars identified as resistant also need to be investigated to define levels of tolerance.

From the data, available conclusions concerning the five major pollutants include: 1) At ambient concentrations of ozone (5-10 pphm) during continuous or intermittent exposure periods, loss in plant fresh and dry weight may approach 15-30%, and yield losses of 5-10% may occur. 2) Losses may occur in the absence of visible injury, but do become greater as visible injury intensifies. 3) Ozone and perhaps other pollutants such as HF affect pollen germination,

Table 5. Summary of types of biological effects studied in air pollution research on floricultural crop plants.

Flower	Pollutant	Weight[z]		Leaf area	Plant ht	Flower		Yield	Ref.[w]
		Foliage[y]	Axillary[x]			Wt.	No.		
African violets	Ethylene						X		1
Begonia	O_3	X				X	X		2
Begonia	SO_2	X				X	X		2
Carnation	O_3	X	X	X			X		28, 29
Coleus	O_3	X				X	X		2
Coleus	SO_2	X				X	X		2
Geranium[v]	O_3	X	X	X		X	X		22, 28
Gladiolus[u]	HF	X		X		X	X[t]	X	13, 47, 67
Marigold	Ethylene						X		1
Petunia	O_3	X		X	X	X	X		2, 21, 22, 37
Petunia	Oxidant	X							58
Petunia[v]	SO_2	X				X	X		2
Petunia	Ethylene					X	X		1
Poinsettia[v]	Oxidant	X							58
Poinsettia	O_3					X[s]			22
Rose	HF	X	X		X		X		14
Snapdragon	O_3	X				X	X		2
Snapdragon	SO_2	X				X	X		2

[z]Fresh and dry wt data are not separated.

[y]Foliage wt information may include both leaf and stem data but these data are not separately identified.

[x]Axillary growth in certain flower crops was evaluated, but not always in terms of fresh or dry wt.

[w]All biological effects tabulated may not appear in each reference listed.

[v]Reduction in anthocyanin content of the flowers was also determined.

[u]Size and wt of corms were also determined (13).

[t]Delay in the opening of florets was also studied (67).

[s]Flower circumference and bract size was measured

Table 6. Types of biological effects studied in air pollution research on fruit and vegetable crop plants.

		Weight[z]		Leaf				Fruit			
Vegetable or fruit	Pollutant	Foliage[y]	Root	Area	No.	Plant ht	Flower no.	Wt	No.	Yield	Ref.[x]
Apple	SO_2							X		X	35
Bean	Oxidant	X		X							36
Bean	O_3	X	X	X		X					5, 26, 57, 61, 68
Bean	Ethylene							X	X		1
Bean	HF	X									95
Bean	NO_2	X									88
Beet	O_3	X	X								70
Beet	SO_2	X	X							X	35
Cabbage	SO_2	X			X						32
Cabbage	O_3	X	X		X	X				X[w]	62,75
Cabbage	Oxidant	X			X	X				X[w]	75
Carrot	O_3	X	X		X					X[v]	75
Carrot	Oxidant		X		X					X[v]	75
Carrot	SO_2		X							X	35
Cauliflower	SO_2	X									4
Cherry	SO_2				X[u]						35
Chinese Cabbage	SO_2	X			X						32
Citrus	SO_2	X			X	X					69
Citrus	HF	X			X						69
Citrus	SO_2+HF	X			X	X					69
Citrus	NO_2							X	X[t]		90
Citrus	Various Pollutants & Combinations							X	X[t]	X	91
Citrus	Oxidant									X[s]	75
Citrus	O_3									X[s]	75
Cucumber	O_3	X									73
Cucumber	SO_2				X	X	X[r]				32
Cucumber	Ethylene								X		1
Currant	SO_2					X[u]					35
Eggplant	SO_2	X			X	X	X		X		32
Gooseberry	SO_2				X[q]					X	34
Grapes	Oxidant	X						X		X	89
Lettuce	SO_2	X	X		X						32
Lettuce	O_3	X	X		X	X					75
Lettuce	Oxidant				X	X				X[p]	75
Onion	O_3	X									73
Pea	O_3	X									71
Pepper	SO_2					X					32
Potato	O_3	X									73
Potato	Oxidant	X								X[o]	45,58
Potato	SO_2									X[o]	34
Radish	O_3	X	X								3,92,93
Radish	SO_2	X	X		X						32,92
Radish	$SO_2 + O_3$	X	X								92,93
Spinach	SO_2	X									35
Strawberry	O_3							X	X	X	75
Strawberry	Oxidant							X	X	X	75
Sweet Corn[n]	O_3	X	X		X	X		X	X	X	39,75
Sweet Corn[n]	Oxidant							X	X	X	75
Sweet Corn	HF					X		X			49
Tomato	NO_2	X			X			X	X	X	86,88
Tomato	SO_2	X			X			X	X	X	32,35
Tomato	O_3	X	X				X	X	X	X	75
Tomato	Oxidant					X		X	X	X[m]	75
Tomato	HF							X	X		87
Turnip	Ethylene	X				X					1
Turnip	SO_2	X	X		X			X	X		32

[z]Fresh and dry wt data are not separated.

[y]Foliage wt information may include both leaf and stem data but these data are not separately identified.

[x]All biological effects may not appear in each reference list.

[w]Dram and wt of cabbage head were evaluated (75).

[v]Wt, shape and size were evaluated.

[u]Shoot growth rather than plant ht was determined.

[t]Leaf and fruit drop were also evaluated.

[s]Yield evaluated in field boxes per tree.

[r]No. of both male and female flowers.

[q]No. of shoots and leaf number were evaluated in gooseberry.

[p]Diam and wt of the lettuce head were evaluated.

[o]Yield of potato tubers was evaluated (34).

[n]Fruit wt and number refers to ear size (74) and wt (39, 74), kernel numbers (39) and wt (39, 49, 74) in the case of sweet corn. Tassel wt and ear characteristics were also evaluated (74, 75).

[m]Tomato fruit quality was also evaluated.

fertilization and fruit set (27, 87). 4) Frequently growth loss is associated with early senescence and leaf drop (90, 91). 5) Sulfur dioxide in low concentrations may initially serve as a nutrient and stimulate growth, but as concentrations increase, slow down growth rates. 6) Nitrogen dioxide limits growth at concentrations below those necessary to cause visual injury (88, 90). 7) Ambient ethylene concentrations are deleterious to growth, flowering and fruit set in certain crops (1). 8) Hydrogen fluoride is important near industrial sources but may have little impact other than accumulating in plant tissue.

Identification of research needs

Research needs for herbaceous and ornamental crop plants have already been identified (44). However, in summary these needs and others pertinent for horticultural scientists can be restated and discussed. We need to identify plant growth and yield changes that are the most severely affected by each of the five major air pollutants, singly and in combination. Plant age and development at exposure must be documented. The effects of air pollutants at various periods throughout the life cycle must be evaluated. We need to determine how environmental conditions interact to influence plant response to air pollutants. There is a need to determine how changes in mineral nutrition affect plant response to pollutants. Do pollutants predispose plants to other pollutants and condition the susceptibility of horticultural crops to infection by biotic plant pathogens and insects? To answer this question necessitates continued study of pollutant-host interactions with biotic organisms and the effects of pollutant combinations on plant response. We need to understand the genetic variation and gene control of plant response. Breeding programs in certain crops need to be established. Research on the mechanism of resistance to pollutants is required so we can understand how pollutants injure plants. We need to assess the economic impacts of air pollutants on horticultural crop production, with some emphasis on quality changes. We need to develop cultural practices to protect crops from air pollutants.

Although the literature may suggest that we have considerable information available concerning the sensitivity of horticultural crops to air pollutants, it is also apparent that this information only serves as a data base to the development of a better understanding of these effects. There are still many questions to be answered. Much additional research, support for research and perhaps new methodology for assessing and describing the impacts of air pollutants on the horticulture industry need to be developed. This review has provided a means of focusing, only briefly, on this problem so that some new understanding and new initiatives can help identify the effects of air pollution on horticultural plants and the environments in which they are grown.

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