Chapter 5

Air Contaminants

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Introduction

A major, often unrecognized variable regulating growth in controlled environments is air contaminants. Little study has been made of contaminants in controlled environments because of the varied spectrum of problem sources.

Many problems are unique to controlled environments and are never, or rarely, seen in outside environments. They become problems in controlled environments because the areas are enclosed and the air is significantly less diluted. Problems may be infrequent because of sporadic production of contaminants from activities such as painting, cleaning, or remodeling in the growth facility area. When toxic contaminants are present in only some chambers, this can pose a particularly serious problem with multichamber research, for contaminant problems may be confounded with treatment effects in the separate chambers and not recognized. This will be most serious if toxicity only produces plant stunting with no obvious visible symptoms of injury.

Air contaminant problems have been suspected and documented by researchers, but in only a few instances has detailed research been undertaken to identify the source and its toxic component. Thus this chapter cannot provide complete details on source, formula, and symptoms for each problem. The chapter has been organized to discuss (1) known sources, (2) specific symptoms, and (3) specific compounds that have been identified as air toxicants.

SOURCES

CHAMBER CONSTRUCTION

The construction materials of every growth chamber pose potential sources of contaminants, most commonly plastic compounds and materials. The problem is compounded because the formulations of many plastic materials vary with different manufacturers and may be changed by a manufacturer at any time. Thus only particular lots of a material may be phytotoxic. The following listing includes construction components that have caused known problems or that release compounds with significant potential for causing phytotoxicity.

Caulking compounds and sealants. A variety of types of silicone and other compounds is used for sealing against air leakage and providing moisture barriers in chambers. The plasticizers of certain formulations are very toxic and have produced toxicity for periods of more than one year (Pezet and Gindrat, 1978). One toxic component, cyclohexylamine (Pezet and Gindrat, 1978) is used as a diluent in caulking compounds sold in tubes. Caulking compounds containing cyclohexylamines smell like rotten eggs. Most caulking compounds in tubes use acetic acid as the diluent, which produces a slightly irritating, sweet odor but is not significantly phytotoxic. The caulking compounds containing cyclohexylamines have produced downward curling of leaves of cucumber and tomato (Pezet and Gindrat, 1978).

An unidentified mixture of sealants and caulking compounds, utilized to reduce air leakage from chambers in a laboratory at Madison, Wisconsin, caused marginal chlorosis and bleaching of the third and fourth developing leaves of lettuce. The leaves recovered to a green color as the plant enlarged if initial bleaching was not too severe. The toxicity of these caulking compounds persisted for at least 6 months after application.

Aluminized Mylar. This material is used to provide reflective surfaces and commonly has an adhesive on the back surface for attachment to the chamber walls. The release of dibutyl phthalate from this material has injured cabbage (Hardwick et al., 1984).

Glazing strips. This plastic material, used between the edge of glass and the framing in greenhouse installations, released dibutyl phthalate and caused severe injury to cabbage and tomato (Hardwick et al., 1984; Hardwick and Cole, 1986).

Paint. The components of paint pose special problems that vary with the different types of paints being used. Oil-based paints have been documented to have toxic xylene and other unidentified toxic components (Seeley, 1976) that can injure leaves and flowers of chrysanthemum. Latex paint has been shown to contain dibutyl phthalates and produce injury to cabbage (Hardwick et al., 1984). Painting a room with a latex wall paint caused black necrotic areas on leaves of seedlings of cottonwood (*Populus deltoides* Bartr) (Dickson, 1979).

Ballasts. The release of ethylene from ballasts is a potential problem (Wills, 1970), but there has been no reported evidence that pinpoints it as a source of any actual problem. Ballasts generally are located on the outside of the chamber, which reduces the risk of toxicity.

Other potential materials. Glues and lubricants used within the chamber could pose problems and should be checked for toxicity. Urethane foam materials commonly are utilized in chamber walls for insulation. These materials contain formaldehyde trapped in enclosed pockets within the foam. Formaldehyde slowly diffuses out of the material (Rossiter and Mathey, 1985) and is a potential problem. Similarly, plywood sheets, particularly resin boards and hardwood plywoods, are formulated with resins that slowly release formaldehyde (Pickrell et al., 1983). The release is slowed if sheets are painted so concentrations in the surrounding air will be reduced, but the potential danger then is extended over a greater length of time.

Humidifier steam. The use of steam from heating plants for humidification may cause problems as a result of chemicals added to steam to control fungi, bacteria, and pH in the steam condensate return lines. Cyclohexylamines, in addition to certain hydrazines, are added to the steam and have phytotoxic potential (Sanford, 1980).

Cooling systems. The leakage of ethylene glycol from a cooling system has been found to produce severe injury to cucumbers that is seen after 5+ days of continuous exposure. The injury is usually seen as tip and marginal chlorosis and necrosis on developing leaves at the apex of the stems and produces a downward cupping of those leaves. With high concentrations and warm temperatures (~30C), a spotted necrosis and chlorotic mottle develops within 48 hours on enlarged leaves. On potatoes only a spotted necrosis has been found.

Chamber Research

Contaminants are emitted by many different substances taken into chambers or rooms in the course of research.

Plastic tubing. Dibutyl phthalate released from flexible polyvinyl chloride (Tygon) tubing has proved toxic to cabbage, radish, and tomato (Hardwick and Cole, 1986; Hannay, 1980). Toxicity was detected from tubing stored for more than 5 years. Not all flexible PVC tubing is made with dibutyl phthalates; most flexible PVC tubing is made with other phthalates, which are much less toxic to plants. Experience to date by the authors indicates that the following tubings are free of injurious volatiles: Teflon, polypropylene, polyethylene, nylon, and rigid polyvinyl chloride.

Plastic screening. Plastic shade screening with bonded fibers was found by the authors to produce stunting and marginal toxicity of lettuce. Plastic screening with loose fibers has caused no such problems.

Mercury thermometers. A broken mercury thermometer can cause serious problems. The mercury can lodge in cracks and will slowly volatilize, causing toxicity to plants. Waldron and Terry (1975) found stunting of sugar beets that was traced to mercury contamination in a growth chamber. Mercury vapors can be detected with ozone analyzers using ultraviolet absorption. Mercury can be cleaned up by dusting the chamber with sodium sulfide crystals and removing the particles by suction (Tibbitts et al., 1977).

Electrical arcing. Arcing in a motor or arcing as a result of electrical short circuits can generate ozone. However, no evidence of problems has been recorded as a result of electrical arcing. Air circulation across plant surfaces and over other organic residues probably removes enough ozone to prevent damaging accumulations.

Plastic containers. Some plastic containers have been shown to contain dibutyl phthalate, thus causing injury to cabbage (Hardwick et al., 1984). Most containers, however, seem to be free of this toxic emission.

Plants. The plants themselves are significant sources of ethylene emissions, particularly during rapid vegetative growth (Wheeler et al., 1992) and when fruits have matured. Plants also emit a variety of volatile hydrocarbons (Batten et al., 1993), as evidenced by the odors emitting from leaves, flowers, and fruits. Plant emissions probably are of little consequence unless chambers are tightly sealed to prevent air exchange.

People. Persons entering a room should be recognized as a significant source of CO_2. This carbon dioxide should be considered a contaminant because increased levels may increase growth of plants. Carbon dioxide levels are discussed in more detail in the chapter on carbon dioxide.

Symptoms

Some symptoms resulting from contaminants in chambers are quite distinctive; therefore, the source of the problem likely can be determined. Other injuries, however, are not as distinctive, and diagnosis can be difficult. Toxicity that only produces stunting of plants without visible symptoms is very difficult to diagnose. When only stunting occurs, contaminant problems may be confounded with treatment effects and not recognized.

Marginal Leaf Bleaching

Bleaching of cucumber, tomato, and beans was seen with cyclohexylamines (Pezet and Gindrat, 1978).

Bleaching of cabbage, tomato, and radish was found with dibutyl phthalates (Hannay, 1980; Hardwick et al., 1984).

Bleaching of the second and third true leaves of lettuce and mung beans was found from unknown caulking compounds (author).

Marginal Leaf Chlorosis

All leaf bleaching symptoms were preceded by chlorotic symptoms for the above-mentioned compounds. Injury was limited to chlorosis if concentrations of toxic compounds were low.

Marginal chlorosis was seen only on mung beans from a bonded plastic screening (author) and on cucumbers from ethylene glycol (Tibbitts and Staub, 1993).

Stunting of Plants

Stunting may result from many of the contaminants at levels less than those that produce observable symptoms. The injury from mercury vapors produced only stunting (Waldron and Terry, 1975).

Cotyledon Necrosis

Cabbage seedlings developed a gray-green marginal collapse, followed by bleaching and necrosis from dibutyl phthalates (Hardwick et al., 1984).

Downward Curling of Leaves

This was reported on cucumber plants from cyclohexylamines emitted by caulking material (Pezet and Gindrat, 1978) and on cucumbers from ethylene glycol (Tibbitts and Staub, 1993).

Abscission of Leaves

This symptom was observed on tomato plants as a result of cyclohexylamines (Pezet and Gindrat, 1978), ethylene (Abeles, 1992), and factors causing oedema (Lang and Tibbitts, 1983).

Galls or Oedema

Galls or oedema, 1-2 mm in diameter and principally on the undersurface of leaves, commonly injures all types of solanaceous plants, sweet potatoes, eucalyptus, and geraniums (Lang and Tibbitts, 1983) in controlled environments. This injury results principally from a lack of ultraviolet radiation in chambers as discussed in the chapter on lighting, but evidence also indicates that some unknown contaminant in controlled environments aggravates the injury (Mitchell and Vojtik, 1967; Lang and Tibbitts, 1983). *Lycopersicon hursutum*, PI LA-1625 is particularly sensitive, as are *L. esculentum* cv. Oxheart (Lang and Tibbitts, 1983).

Identified Compounds

Cyclohexylamines: (Pezet and Gindrat, 1978)

Sources—caulking compounds, steam

Dosage—unknown

Sensitive plants—tomatoes, cucumbers,

green beans

Dibutyl phthalate: (Hardwick et al., 1984; Hardwick and Cole, 1986)

Sources—flexible polyvinyl chloride tubing, glazing strips, hoses, pots, latex paint, aluminized plastic sheeting

Dosage—0.3 ppb for 3 hrs

Sensitive plants—Derby Day cv. of cabbage

Mercury: (Waldron and Terry, 1975)

Sources—thermometers

Dosage—unknown

Sensitive plants—roses, sugar beets

Xylene: (Seeley, 1976)

Sources—paint

Dosage—unknown

Sensitive plants—cvs. of chrysanthemum

Ethylene: (Abeles, 1992)

Sources—ballasts, plants

Dosage—10 ppb for 4 hrs

Sensitive plants—tomatoes

Ethylene glycol: (author)

Sources—liquid in cooling systems

Dosage—unknown

Sensitive plants—cucumbers

Control

Injury from air contaminants is best controlled by ventilating the area in which growth chambers are located with a large amount of fresh air. A recirculating air-handling system should circulate at least 20% fresh air in the growth chamber area with each cycle, regardless of the outside air temperature. Most chambers and rooms have sufficient leakage that forced ventilation into the chambers is not necessary, but if chambers or rooms are totally sealed, fresh air should be provided to obtain as close to one volume of fresh air each 5 minutes as possible. The addition of fresh air into the chamber area and into growth chambers will help maintain more uniform CO_2 levels as well as minimize contaminant problems. As discussed in the chapter on carbon dioxide, the concentration of CO_2 will vary greatly with human activity around the chambers.

Activated charcoal filters help absorb and reduce levels of certain contaminants in tightly sealed chambers, but may not provide adequate control of all contaminants or in chambers with high air-exchange rates. Removal of ethylene is accomplished by utilizing brominated activated charcoal. It is recommended, however, that a two-stage filter be used when scrubbing the ethylene, with the air passing first through the brominated charcoal and then through plain activated charcoal to remove any trace amounts of volatile bromine.

Testing for Toxicity

An effective way of testing for phytotoxicity of materials has been described by Hardwick et al. (1984). This method uses 1.5 liter open-ended glass cuvettes (Fig. 1) placed on pots with plants and with the top of the cuvette covered by muslin. The plastic under test was suspended on a

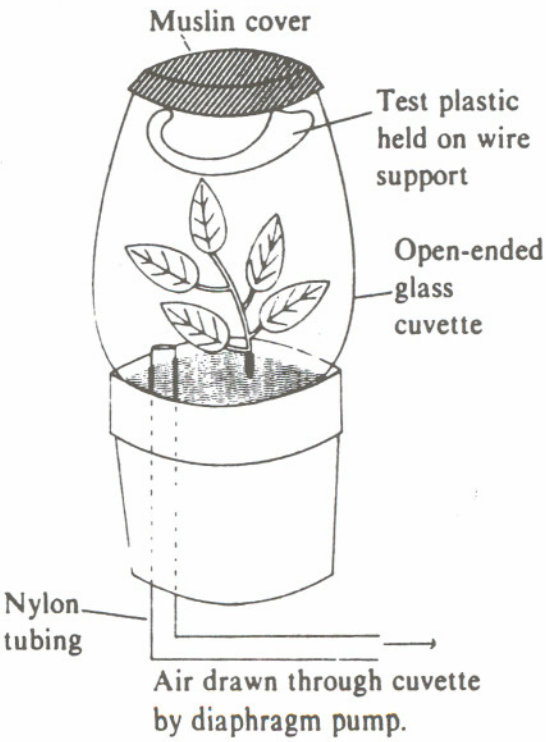

Figure 1. Toxicity test apparatus.

wire support at the top of the cuvette. The cuvette was ventilated at approximately 2.5 air exchanges per hour with a diaphragm pump.

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