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AIR QUALITY ENHANCEMENT BY HORTICULTURAL ENGINEERING

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Abstract. **Frequently, a significant portion of air pollutants escape from industrial operations even though the operations employ the best available control technology. These fugitive pollutants may be removed from the ambient air under relatively stable meteorological conditions, especially when air flow rates are slow, by a perimeter planting of carefully selected plant material. Such a process might be termed Horticultural Engineering because of a similarity to Chemical Engineering. The concept of scrubbing may also be applied to roadsides and heavily urbanized areas.**

Air pollutants such as sulfur dioxide and acid fluorides are effectively scrubbed from air in a local situation by vegetation. Increasing industrialization, urbanization and fossil fuel combustion, together with decreasing environmental quality control, suggest that plants could be used to combat local air pollution problems at points of pollution, thereby contributing to an aggregate improvement.

Chemical and industrial engineering have adopted technology to control air pollution; however, there are usually fugitive emissions not subject to control. It is to attack this residual problem that Horticultural Engineering may develop a technology, methods and procedures to scrub ambient air masses as they flow away from localized point sources of air pollution. An example of such a problem is fluoride emanations from gypsum ponds. These emanations would most likely constitute a problem under a relatively stable, slow-moving air mass, which would collect fluoride from the acid waters and transport them, affecting nearby plants and animals before dispersing into surrounding areas. A perimeter planting of trees and/or shrubs would be helpful in reducing the locally serious problem. Also, these plantings should be selected to beautify the industrial area.

Sulfur dioxide and fluoride are highly phytotoxic air pollutants. These two compounds are ranked within the top five in importance with respect to the amount of plant damage (35). Their detrimental effects occur at relatively low concentrations. Sulfur dioxide is toxic at the parts per million (ppm) level while fluoride is toxic at the parts per billion (ppb) level.

Impact of SO_2 and F on vegetation has been documented extensively (1-7, 9, 12-30, 32-40). Airborne pollutants enter plants primarily via stomates in the leaves and is carried through the transpirational stream causing chlorosis and/or necrosis of margins and tips of leaf blades (2, 12, 23). Characteristic chlorosis and necrosis develops because of the accumulation of F at these locations (34, 35). Toxic symptoms of acute SO_2 exposure appear as small necrotic lesions between the veins and along the leaf margin, which may extend toward the midrib interveinally while necrotic areas coalesce (1). Chronic SO_2 injury develops from lower level exposure and appears as general chlorosis (1).

Plant metabolism is disrupted by SO_2 and F and may alter various chemical pathways in pollutant sensitive plants. Enzymes such as malate dehydrogenase, phosphatase and hexokinase are fluoride sensitive (23, 24) and ribulose diphosphate carboxylase and phosphoenolpyruvate carboxylase are SO_2 sensitive (38, 39). Both gases affect the uptake of oxygen and carbon dioxide (14, 15, 23, 35). Photosynthesis and chlorophyll content decline from SO_2 and F exposure (5, 7, 19, 35). Leaves fall off, new growth declines, flowers and fruits are lost, overall fitness is altered and yield and plant quality decrease (1, 6, 7, 9, 16, 17, 19, 21, 35).

Light, relative humidity, temperature, wind speed and edaphic conditions may increase or reduce a plant's resistance (5, 26, 33, 35). Individual characteristics such as physiological age, water status, internal nutritional balance, stomatal conductance and anatomy of a plant will determine relative susceptibility (4, 6, 14, 26, 37). Distance from the emission source and the concentration and duration of exposure control the amount of damage done to exposed plants (32, 35). Finally, combination of SO_2 with F may cause different responses from plants than either gas alone (18, 21, 25, 28).

Most pertinent to this discussion is the great diversity which exists between plant species in resistance to SO_2 and F among plant species (1, 3, 5, 7, 8, 9, 10, 13, 28, 35, 40). Differences may be related to the exclusion of the gases or by the metabolism enabling the detoxification or purging of the gases once they enter living tissue (7, 20, 26, 36). Great potential exists for breeding trees for resistance to air pollution based on individual differences with species (8, 9, 10, 11, 13, 28, 31). Tolerant plant material has been identified and may offer great potential in polluted environments (13).

The usefulness of tolerant species to scrub air pollutants from the air is evident (20, 29, 30). Relative amounts of absorbed gaseous pollutant do not necessarily correspond to symptom expression (3), and symptom expression may not lead to growth reduction (28). Woody plants can significantly reduce the amounts of SO_2 in the air in close proximity of the foliage (20, 30). This is a "boundary effect" in that greatest uptake of atmospheric SO_2 occurs nearest the plant and the concentrations increase with distance from the absorptive area (20). Biofiltration will not occur at a constant level since environmental changes will affect stomates which affects gas exchange. Changes in humidity, temperature, water and light cause changes in stomatal aperture and these conditions can modify or override normal gas exchange patterns. In Florida, a typical summer day provides conditions of high humidity, high light intensity and elevated temperature all conducive to optimum gas exchange. A cool, dry, overcast situation will reduce gas exchange. Over a prolonged period it seems likely that a barrier of vegetation can be an effective absorptive entity (20). Even at night plants could be effective as adsorptive surfaces, especially on nights with heavy condensation.

Specific objectives in the Horticultural Engineering approach include the following:

1. Develop and apply the concept of "Horticultural Engineering" to polluted areas in pursuance of enhanced air quality and improved industrial environment.
2. Select and screen trees and shrubs adaptable to atmospheric scrubbing and enhancement of the environment esthetically. Plants must have acceptable horticultural qualities, namely to grow rapidly and serve as attractive landscape specimens.
3. Evaluate acceptable plants for sensitivity to sulfur dioxide and hydrofluoric acid fumigation.
4. Chemically evaluate the capacity to accumulate F and SO_2 from a moving air mass and quantify the capacity to detoxify the gas, i.e. to return it to the environment in a harmless form such as leached KF or as sulfide emissions from plants which thereby reduce the SO_2 and F levels in the atmosphere.
5. Project the practicality of the Horticultural Engineering procedures for specific types of SO_2 and F problems and problem areas.

Steps in developing the Horticultural Engineering for Air Quality enhancement include the following:

1. Identify problem areas that are likely subjects for improvement and categorize according to needs and opportunities.
2. Prepare a likely scenario for each problem area in regard to pollutants and appropriate corrective measures keeping in mind Ornamental Horticulture and landscape coordination with the air problem.
3. Develop a pool of plant species categorized according to suitability for various jobs. Plants must be adapted to a location where needed based on soil, culture, water, fertilizer and local climate and they must tolerate the pollutant in question. Selected species must effectively scrub and detoxify the pollutant and must have adequate growth rate, canopy and biomass to do the job.
4. Make pilot plant plantings at sites of air pollution control, estimate the actual scrubbing accomplished by plant and air analysis, and relate leaf effectiveness to total foliar canopy produced.
5. Run a cost-benefit analysis, including a factor for esthetic value, and project the effectiveness of the procedure.

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SYMPTOMOLOGY AND RELATIVE SUSCEPTIBILITY OF VARIOUS ORNAMENTAL PLANTS TO ACUTE AIRBORNE SULFUR DIOXIDE EXPOSURE[1,2]

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Abstract. **The effect of airborne sulfur dioxide on ornamental plants was examined by comparative greenhouse fumigation of various foliage plants, landscape ornamentals, and flowering ornamentals at 0, 0.5, 1.0, and 2.0 ppm SO_2. Selected SO_2 levels allowed placement of plants into very low, low, intermediate, high and very high susceptibility categories based on foliar injury. Foliar symptoms included marginal and interveinal necrosis and enhanced chlorosis. Flowers generally were not affected by SO_2 exposure, but occasionally were the most susceptible organ.**

Fossil fuel combustion is the major source of sulfur dioxide (SO_2) air pollution and electrical generation accounts for approximately 73% of this country's SO_2 emissions (7). Since 90% of global fossil fuels is coal, conversion of electrical plants from oil- to coal-burning facilities is inevitable and has begun due to depletion of world oil reserves. This conversion will contribute increasing amounts of SO_2 to the atmosphere. As populations increase, particularly in Florida, electrical facilities will increase in number and add to a worsening atmospheric condition.

The impact on ornamental horticulture may be occassional, but severe. Economic loss to horticultural crops due to SO_2 pollution will be increasingly significant. Serious damage to plants at the nursery makes them unmarketable products, and in the urban landscape causes aesthetic and economic loss.

Susceptibility to SO_2-induced injury varies within and among plant species (1-6, 8, 9, 11). Information on species commonly grown in Florida with regard to their susceptibility-tolerance levels will facilitate the diagnosis of SO_2-induced injuries and aid in the establishment of cultural practices to avoid potential hazards near SO_2 emission areas. This report describes susceptibility of various ornamental plants to airborne SO_2 as determined by comparative fumigation techniques.

Materials and Methods

Forty-three types of plants were evaluated for susceptibility to acute SO_2 exposure and were categorized as landscape, foliage or flowering plants (Table 1). All landscape and foliage plants were fumigated soon after acquisition from local nurseries. Flowering plants, however, were obtained as seedlings or grown from seed to maturity at the AREC-Bradenton.

Fumigations were conducted over a period of several months from February through May, 1981. Exposure to SO_2 was carried out in 7 fumigation greenhouses as previously described by Woltz and Waters (10). Five flowering plants or 4 foliage or landscape plants of each type were placed randomly in each greenhouse one day prior to exposure. Two houses received 0.5 ppm SO_2 for 8 hrs, 2 houses received 1.0 ppm SO_2 for 4 hrs, 2 houses received 2.0 ppm SO_2 for 2 hrs, and 1 house was a non-fumigated control. A cylinder of compressed SO_2 (1.5% in air) was used as the fumigant source and was metered into the houses via a fan which drew ambient air through evaporative cooling pads. Greenhouse atmosphere (24 m^3) was exchanged once every 2 minutes. SO_2 concentrations were monitored by a Thermo-Electron Model 43 SO_2 Analyzer calibrated with permeation tubes in a Metronics Dyna-calibrator. Fumigations began at 9 AM and were conducted on sunny days.

Relative humidity and temperature varied with outside conditions over several months and ranged from 25-85% and 10-38°C, respectively. Generally, light intensity in the greenhouses was 30% of full sunlight.

One to 3 days after fumigation plants were rated visually for percent leaf area necrosis and symptomology of SO_2 injury to each species was recorded. Plant were placed in 1 of 5 categories for susceptibility to acute SO_2 exposure. These categories were very high, high, medium, low and very low susceptibility to SO_2-induced damage. Categories were chosen based on relative comparison of a species' injury or lack of injury to others tested, and to geranium, a plant of known susceptibility to SO_2. A photographic library was compiled to facilitate accurate symptomological descriptions.

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