Ozone Damage Detection in Cantaloupe Plants*

Ozone-damaged plants were distinguishable from nondamaged plants by reflectance measurements in the 1.35- to 2.5-μm near-infrared water absorption waveband.

INTRODUCTION

Ozone (O₃), which may reach a concentration of 70 parts per hundred million (pphm) in the Los Angeles basin, is probably the most important air pollutant affecting plant growth, development, and reproduction in the United States (Walker and Barlow, 1974). Ozone causes as much as 90 percent of pollution injury to vegetation (Marx, 1975), some of which is invisible and can produce atomic oxygen (O) that combines with O₂ in the air to form O₃. Some O₃ may descend to the Earth's surface from the stratosphere, or it can be formed from electrical storms and electrical discharges (Heggestad and Heck, 1971).

Literature published before 1971 on plant responses to air pollutants, including O₃, was intensively reviewed by Heggestad and Heck (1971). Usually O₃ causes small necrotic spots to develop on the upper (adaxial) surface of fully-expanded leaves of herbaceous plants (Heggestad and Heck, 1971), and injures their palisade cells first (Evans and Ting, 1974; Heggestad and Heck, 1971; Howell and Kremer, 1972; Thomson et al., 1966). On grasses without palisade cells, O₃ injury develops in the leaf mesophyll and on both upper and lower (abaxial) leaf surfaces (Heggestad and Heck, 1971).

We studied effects of O₃ damage on the

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reflectance and photographic responses of cantaloupe plant leaves and canopies to determine the best wavelengths to detect O₃ damage and to determine if O₃ damage could be detected before lesions became visible.

**Materials and Methods**

We conducted preliminary O₃ studies on eight 3-week-old vegetable plants—cucumber (*Cucumis sativus* L., cv Ashley); cantaloupe (*Cucumis melo* L. var. cantalupensis Naud., cv Perlita); cowpea (*Vigna sinensis* Savi, cv unknown); sweet pepper (*Capsicum annum* L., cv Rio 66); squash (*Cucurbita pepo* L., cv Early Prolific Straightneck); lima bean (*Phaseolus limensis* Macf., cv Jackson Wonder); pinto bean (*Phaseolus vulgaris* L., cv Pinto); and watermelon (*Citroillus vulgaris* Schard., cv Charleston Gray)—exposed to 16 pphm of ozone for 2 h in a 0.17 m³ plexiglass chamber (Craker and Manning, 1972, 1973).

About 24 h later, the cucumber's, cantaloupe's, and cowpea's foliage showed more O₃ damage than did those of the other five crops. Therefore, we selected cantaloupe plants for further O₃ studies. The plants for the preliminary study were grown in a different greenhouse than those below.

We planted five seeds in each of 50 0.2-liter plastic pots, containing a sandy clay loam mixed with a 10-25-5 fertilizer to give an N rate equivalent of 67.2 kg/ha. The experiment was conducted in a greenhouse and the pots were subirrigated. About three weeks after plant emergence, 25 pots were placed in each of two plexiglass chambers for two simultaneous treatments—one aerated (control) and the other O₃-treated. An O₃ meter (MASTI 724-2) connected to the spectrophotometer's light beam was imaged only on O₃-damaged areas. Data were corrected for decay of the barium sulfate standard to give absolute radiometric data (Allen and Richardson, 1971). Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer. Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer. Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer. Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer.

For the reflectance measurements, we photographed a representative leaf for each treatment. However, the film was ruined during processing (this was known 26 h later). We rephotographed other leaves after they had been exposed to some sunlight. Nevertheless, Plate 1 typifies the control and O₃-damaged leaves that were used for spectral measurements.

Immediately after we collected each leaf, we wrapped it in Glad wrap (plastic wrap) to minimize dehydration and transferred it to the laboratory for measurements. Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer. Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer. Leaf reflectance, thickness, green weight, and area were measured with a spectrophotometer.

Total diffuse reflectance of upper (adaxial) surfaces of single leaves over the 0.5- to 2.5-μm waveband was measured with a Beckman Model DK-2A spectrophotometer, equipped with a reflectance attachment. To measure the reflectance of O₃-treated leaves, the spectrophotometer's light beam was imaged only on O₃-damaged areas. Data were corrected for decay of the barium sulfate standard to give absolute radiometric data (Allen and Richardson, 1971). Leaf thickness was measured by using a linear displacement transducer and digital voltmeter (Heilman et al., 1968). Leaf areas were measured with a planimeter. Water content was determined on an oven dry-weight basis by drying leaves at 68°C for 72 h and cooling them in a desiccator before final weighing.

For the reflectance measurements, we used seven wavelengths from the 41 wavelengths measured over the 0.5- to 2.5-μm waveband—0.55 μm (green reflectance peak), 0.65 μm (chlorophyll-absorption band), 0.85 μm (near-infrared plateau), 1.45 μm (water absorption band), 1.65 μm (reflectance peak after water-absorption band at 1.45 μm), 1.95 μm (water absorption band), and 2.20 μm (reflectance peak after water-absorption band at 1.45 μm).
reflectance peak after water absorption band at 1.95 μm). We analyzed reflectance data for each of these wavelengths for variance and used Duncan’s multiple range test to test differences among treatment means, p = 0.01 (Steel and Torrie, 1960).

Tissue pieces from near the center of leaves were fixed in formalin-acetic acid-alcohol, dehydrated with tertiary butanol, embedded in paraffin, stained with safranin-fast green, and transversally microtomed at 12-μm thickness (Jensen, 1962). Photomicrographs were obtained with a Zeiss Standard Universal Photomicroscope. This was done to relate internal leaf structure with reflectance.

In order to support laboratory results, control and O₃-treated cantaloupe plants contained in flats were taken from the greenhouse to the field where their canopies were measured spectroradiometrically. Reflectances of control and ozone-treated plant canopies were measured over the 0.5- to 2.4-μm waveband 1 hr after treatment with a ground-based Exotech Model 20 Spectroradiometer (Leamer et al., 1973). Its sensor had a 15-degree field-of-view (0.08m²) at 1.2 m above the plant canopies.

In order to determine whether O₃ leaf damage could be detected before it was visible, we simultaneously compared control and O₃-treated plants visually and photographically. We photographed the plants hourly in a photographic laboratory with a Polaroid Land Camera Model 108 using Pola-Color film-type 108, and with a Hasselblad camera, using 70-mm Kodak Aerochrome infrared film 2443 (infrared color) and a yellow Hasselblad filter. The only light source was provided by 75 Watt incandescent Grow Light bulbs (Kyung-hung Trading Company, Box 635, Central Seoul, Korea), whose primary spectral output was blue light.

**RESULTS AND DISCUSSION**

**LEAF STRUCTURE**

Internal leaf structures for the control and for lightly, severely, and very severely O₃-damaged leaves are shown in Figure 1, A, B, C, and D, respectively. Leaf structure had collapsed from dehydration for severely (C) and very severely (D) O₃-damaged leaves as compared with the control (A) and lightly O₃-damaged leaves (B). Leaf water contents ranged from 82.6% for very severely damaged to 90.3% for control leaves.

**REFLECTANCE SPECTRA**

Laboratory reflectance spectra over the 0.5- to 2.5-μm waveband are shown in Figure 2 for the control and for the lightly, severely, and very severely O₃-damaged cantaloupe leaves.

Mean light reflectances at the 0.55 and 0.65-μm wavelengths in the visible region (0.5 to 0.75 μm) among the control, and
PHOTOGRAPHIC DETECTION

We compared hourly visual and Polaroid photographic results to determine if $O_3$ leaf damage could be detected before it was seen. We detected $O_3$ leaf damage photographically as light brownish-colored areas (Cardenas et al., 1969-70; Cardenas et al., 1972; Leamer et al., 1978), 16 h before we could see it (38 h after treatment). Infrared photos as compared with the Polaroid photos did not show $O_3$ damage. Apparently, the predominantly blue light source was responsible for our success in detecting $O_3$ damage with Polaroid photography. However, possibly more work with different films, filters, and light sources will give even earlier detection of $O_3$ leaf damage than we have obtained.

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REFERENCES


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