

Air Pollution Effects on Vegetables

Gerald E. Brust, IPM Vegetable Specialist, May 2007

The burning of coal and other fossil fuels gives rise to various chemical pollutants such as SO₂ (sulfur dioxide), NO_x (nitrogen oxides such as nitrite, nitrate, etc.), O₃ (ozone) as well as a variety of other hydrocarbons. Ozone and peroxyacetyl nitrate (PAN) produced in these reactions can become injurious to plants depending on concentration and duration of exposure. Ozone causes up to 90 percent of the air pollution injury to vegetation in the United States and negatively influences plant growth and development causing decreases in yield. Ozone injury to watermelons is common in the mid-Atlantic area. After ozone, PAN is the next most phytotoxic air pollutant.

Movement of Pollutants into Plants: Most of the polluting gases enter leaves through stomata, following the same pathway as CO₂. NO_x dissolves in cells and gives rise to nitrite ions (NO₂⁻, which is toxic at high concentrations) and nitrate ions (NO₃⁻ that enter into the nitrogen metabolism of the plant as if they were absorbed by the roots). In some cases, exposure to pollution, particularly SO₂, causes stomates to close, which protects the leaf against further entry of the pollutant but also stops photosynthesis. In the cells, SO₂ dissolves to produce sulfite ions, which can be toxic, but at low concentrations they are effectively detoxified by the plant. SO₂ air pollution can actually provide a sulfur source for the plant.

Crops Affected: Tomato, watermelon, squash, potato, string beans, snap beans, pinto beans, tobacco, soybeans, cantaloupe, muskmelon, alfalfa, beets, sunflower, carrots, sweet corn, gourds, green peas, turnips, grapes, peaches, and strawberries are some of the more susceptible crops to air pollution damage. Cucumbers, pumpkins, and peppers are less susceptible. Watermelon and squash are the most sensitive of the cucurbits followed by cantaloupe.

Symptoms: Ozone: Ozone is considered the most damaging phytotoxic air pollutant in North America. Injury is most likely during hot, humid weather with stagnant air masses.



Fig. 1 Ozone damage to potato
Photo courtesy of Gerald J. Holmes, NCSU

Symptoms consist of small, irregular shaped spots or flecks that range in color from dark brown to black or light tan to white (Fig.1). Symptoms also include stipples (small darkly pigmented areas approximately 2-4 mm in diameter), bronzing, and reddening. These symptoms usually occur between the veins on the upper leaf surface of older and middle-aged leaves, but may also involve both leaf surfaces for some species and cultivars (Figs.1 and 2).

The type and severity of injury depends on the duration and concentration of ozone exposure, weather conditions, and plant genetics. Some or all of the symptoms can occur on vegetables under various conditions.

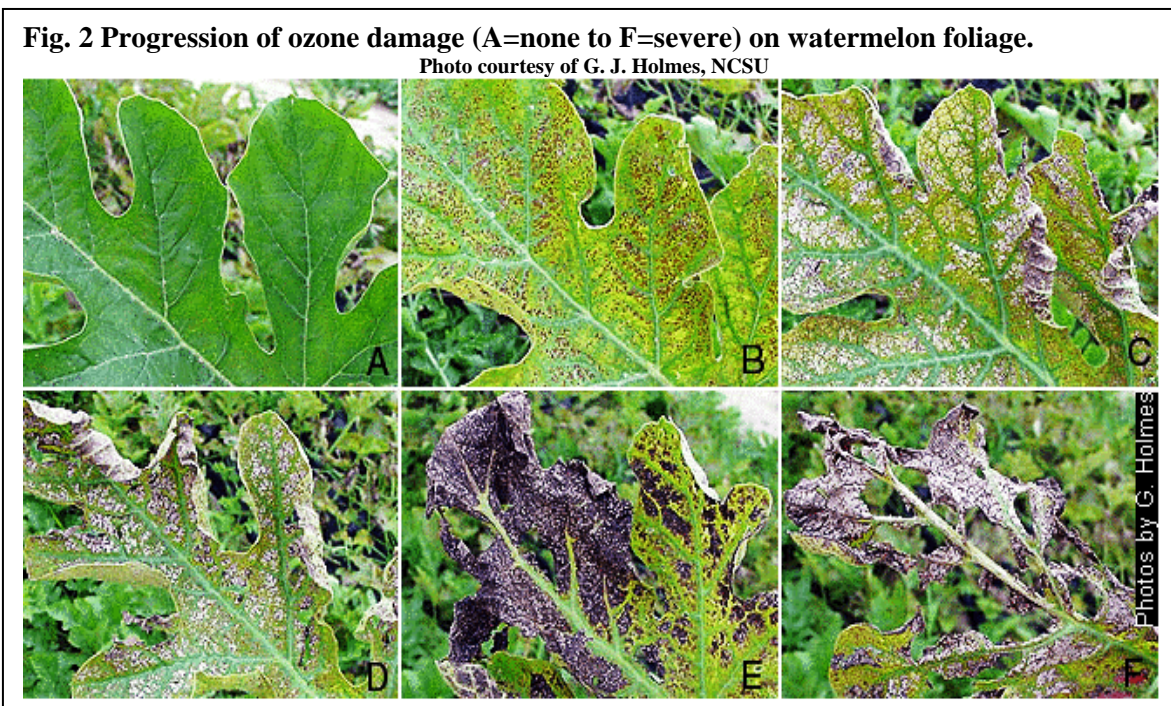
Symptoms on one cultivar can differ from the symptoms on another. With continuing ozone exposure the symptoms of stippling, flecking, bronzing, and reddening are gradually replaced with chlorosis and necrosis (Figs. 2d and e). Early ozone foliar damage (Figs. 2b and c) can resemble severe spider mite injury. The presence of mites can be confirmed by examining the underside of the leaf. Mite populations would have to be comparatively great (≥ 45 /leaf) to cause the type of leaf injury shown in Figs. 1b and c.



Fig. 3 One side of stem with severe O₃ damage
 Symptoms of ozone damage can appear on one side of a plant or stem depending on the source of pollution and micro-climate (Fig. 3).

As the exposure to ozone continues the spots may fuse forming larger necrotic areas (Figs. 2d and e). Due to the tissue collapse induced by ozone, leaves are prone to infection by pathogens such as *Alternaria* sp (early blight) and will senesce sooner. Plants that are exposed to high ozone concentrations metabolize less carbon dioxide, resulting in less carbon available for soil microbes to utilize. Consequently, soil enrichment and carbon processing decline resulting in decreased soil fertility. Symptoms

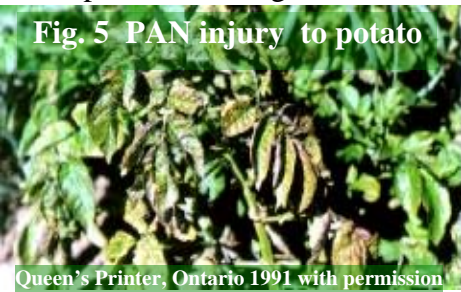
The injury pattern on the foliage is initially observed on older mature leaves near the crown or center of the plant, often progressing with time to the younger foliage. The yellowing of the plant centers in rows of watermelon is quite distinctive and can give fields an obviously striped pattern of alternating yellow and green bands. This type of injury on watermelon can be referred to as "center of the crown dieback." In contrast, injury on muskmelons is typically much less severe and is visible at a later stage of plant development. Irrigated plants will promote greater symptom development if the cultivar is sensitive compared with drought-stressed plants. Ozone injury on watermelons generally appears in mid to late July prior to fruit maturation. Ozone injury on beans appears as bronzing on the upper leaf surface and as the problem progresses necrotic lesions are formed that coalesce and become reddish brown.



Sulfur dioxide: Damage symptoms to crops caused by SO₂ and its by-product sulfuric acid usually result in dry, papery blotches that are generally white, tan, or straw-colored and marginal or interveinal (Fig. 4). On some species, chronic injury causes brown to reddish brown or black blotches. Both the upper and lower leaf surfaces are affected. Leaf veins remain green. Young and middle-aged plants and leaves are most sensitive. Sensitivity is highest during days with bright sunlight and high relative humidity.



Peroxyacetyl nitrate (PAN): Causes a collapse of tissue on the lower leaf surface of most plants resulting in leaves that develop bands or blotches of glazed, bronzed or silvery areas (Fig. 5). The affected leaves usually senesce prematurely. On some plants, such as Pinto bean, tomato, and tobacco, the injury can occur through the entire width of the leaf blade. PAN is most toxic to small plants and younger leaves, but leaves just forming and starting to open and the most mature leaves are less susceptible to PAN injury. The formation of PAN is well documented on the west coast of the U.S., with injury occurring on vegetation all along the coast, however, little is known about the concentration of PAN in the eastern United States.



Nitrogen Oxides (NOs): These pollutants play a major role in the production of ozone. NOs are likely contributors to a number of environmental effects such as eutrophication in coastal waters like the Chesapeake Bay. Eutrophication occurs when bodies of water undergo an increase in nutrients that reduce the amount of oxygen in the water, thereby producing an environment that is unfavorable to animal life. It is estimated that 50 million pounds of nitrogen make it into the Chesapeake Bay through deposition of NOs onto the Bay's watershed (Cercio and Noel, 2004).

Ethylene: (C₂H₄) occurs in trace amounts in propane, gasoline and natural gas and is produced when these substances are burned. It also is present in wood and tobacco smoke. Ethylene pollution influences the activities of plant hormones and growth regulators, which affect developing tissues and normal organ development, without causing leaf-tissue damage. Injury to broad-leaf plants occurs as a downward curling of the leaves and shoots (epinasty), followed by a stunting of growth. In high tunnels, which burn propane, kerosene or use motors that burn gasoline, that have poor or no ventilation, even minute amounts of this pollutant can cause severe damage to tomatoes. Tomato plants exposed to ethylene can develop plant twisting, defoliation, and bloom drop.

Estimated yield losses: Estimating yield loss due to air pollutants in the field is difficult and only approximations are available. In a California study, ozone damage to crops caused the greatest yield losses (10-30%) in cantaloupe, grape, onion, and bean. Sorghum and lettuce yields were found to be mostly unaffected by exposure to ozone.

Other research has shown that when average daily ozone concentrations reach ≥ 50 ppb (parts per billion); yields of vegetables can be reduced by 5-15%.

Management: While there is no treatment for ozone injury it may be possible to select certain cultivars that are more tolerant of air pollution compared with others. Little research has been done in this area; however, a watermelon/ozone study by Holmes and Schultheis (2001) in North Carolina showed that seedless cultivars tended to be more tolerant of ozone damage than seeded cultivars. The top 10 least susceptible watermelon cultivars in descending order were: W5051, W5052, Millionaire, HMX913, EX4590339, Freedom, HMX8914, Revolution, Millennium, and TRI-X 313. The 10 most sensitive cultivars in ascending order were: SXW 5023, Variety 800, Stars-N-Stripes, Pinata LS, Athens, WX8, Regency, ACX 5411, Starbrite, and Variety 910.

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