ETHYLENE EFFECTS ON POSTHARVEST FRUIT DISEASES

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Ethylene in air or controlled atmosphere (CA) storage can influence fungal growth and disease development on harvested horticultural crops. Since ethylene enhances senescence of fresh fruits and vegetables, it can increase their susceptibility to pathogens. Also, ethylene may have a direct stimulatory effect on the growth of some fungi and consequently disease incidence and severity in host tissue. On the other hand, ethylene can induce formation of phytoalexins or other antifungal compounds in certain commodities and increase their resistance to pathogens. In this brief review the role of ethylene in postharvest pathology of horticultural crops will be discussed.

Direct Effects of Ethylene on Fungal Growth

Ethylene effects on pathogens vary among species and depend on ethylene concentration, exposure time and temperature, as well as composition of the atmosphere (oxygen and carbon dioxide concentrations). While Archer (1) reported that ethylene at 10 or 100 ppm did not influence growth of 22 species of fungi, Kepczynski and Kepczynska (12) found stimulation of spore germination of *Botrytis cinerea*, *Penicillium expansum*, and *Rhizopus stolonifer* in response to 100 ppm ethylene at room temperature. They also reported that exposure to 10,000 ppm ethylene inhibited germination of these 3 fungi. El-Kazzaz et al. (8) found that ethylene at 1, 10, 100, and 1000 ppm significantly stimulated spore germination at 20°C of *Penicillium digitatum*, *Penicillium italicum*, and *Thielaviopsis paradoxa*, but it had little or no effect on *Alternaria alternata*, *Botrytis cinerea*, *Colletotrichum gloeosporioides*, *Monilinia fructicola*, *Penicillium expansum*, and *Rhizopus stolonifer*. These ethylene treatments stimulated germ tube elongation of most of the tested fungi, but had minor effects on their apparent growth rate as determined by colony diameter at 20°C. However, when the total dry weight as indicated by glucosamine content was used to quantify fungal growth, ethylene effects on stimulating fungal growth were observed for *Botrytis cinerea* and *Penicillium italicum in vitro* and in strawberries and oranges, respectively (8).

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Stimulatory Effects of Ethylene on Disease Development

Several researchers (2,3,5,9,10,15,16,17) noted that exposure of citrus fruits to ethylene concentrations above 10 ppm increased decay incidence and severity, which may have been largely due to accelerated senescence of the rind tissues. Brown and Barmore (5) reported that resistance in orange-colored tangerines was broken down by subjecting them to 100 ppm ethylene for 76 hours. Barmore and Brown (2) reported that incidence of stem-end-rot (caused by Diplodia natalensis) of Valencia oranges increased with exposure to increasing concentrations of ethylene from 0 to 50 ppm at 30°C. Hyphal penetration from latent infections in the button into the area of abscission occurred more rapidly after the oranges were exposed to ethylene at 50 than at 1 or 10 ppm (2).

El-Kazzaz et al. (7) found that the presence of 20 ppm ethylene in air or in CA (2.3% oxygen + 5% carbon dioxide) resulted in more decay development on strawberries inoculated with Botrytis cinerea and kept at 1 or 3°C for 7 or 21 days. The effects of ethylene on stimulating fungal growth were much more noticeable when added to air than when combined with CA. For example, the mean lesion diameter in 'Aiko' strawberries was 7.5, 39.1, 11.8, and 16.6 mm on fruit kept in air, air + ethylene, CA, and CA + ethylene, respectively (7). It appears that ethylene may increase decay development on plant tissues by accelerating their softening and senescence and/or by inhibiting the formation of fungitoxic compound by the host tissue. In either case, the pathogen will grow faster and disease development is enhanced.

Possible Involvement of Ethylene in Resistance of Plant Tissue to Disease

An important mechanism for disease resistance in plants and plant organs is their ability to accumulate relatively simple chemical substances (phytoalexins) rapidly to levels inhibitory to the growth and development of pathogens. Many abiotic and biotic factors can cause the accumulation of phytoalexins in plant tissues (13); ethylene may be one of these factors.

Ethylene has been shown to induce resistance to certain pathogens in some harvested plant organs. Sweet potato slices exposed to 8 ppm ethylene for 2 days became resistant to infection by Ceratocystis fimbriata, the causal agent of black rot (19). This increased resistance was accompanied by an increase in peroxidase and polyphenol oxidase activities. Lockhart et al. (14) found that ethylene treatment inhibited apple rot development caused by Gloeosporium album. Green-colored 'Robinson' tangerines exhibited resistance to Colletotrichum gloeosporioides when treated with ethylene for 3 days before inoculation, and then exposed to additional ethylene to complete degreening (5). Brown (4) reported that ethylene-treated tangerines accumulated more phenolic compounds and were more intensely lignified than untreated fruit.

El-Kazzaz et al. (6) found that exposure of oranges to 1000 ppm ethylene at 20°C for 2 to 6 days before inoculation with Penicillium italicum reduced fungal growth as indicated by lesion diameter and glucosamine content. Total phenolics of rind tissues increased in inoculated fruit, but not in uninoculated oranges, in response to the ethylene treatment. Phenylalanine ammonia-lyase (PAL) activity increased significantly in the rind of ethylene-treated oranges (6,18). PAL may play a role in the synthesis of phytoalexins or other anti-fungal compounds (11,18), which enhance the resistance of plant tissue to pathogens.

Future Research Needs

More research is needed to quantify the effects of ethylene at various concentrations in air or in CA and durations of exposure on fungal growth in vitro and in vivo at various temperatures. This will help clarify the inconsistencies among the few published reports. The possible interactions of ethylene with reduced oxygen and/or elevated carbon dioxide levels in the atmosphere should also be studied. Further research is needed to elucidate the biochemical basis of ethylene-induced resistance against pathogens in harvested horticultural commodities.

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