# New Technologies for Working with Ethylene

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Ethylene gas, a common air pollutant and powerful plant growth regulator (or hormone) is a two-edged sword in the handling of perishables. As a plant hormone it is a trigger for many of the key events in plant growth and development, events as diverse as: seed germination; shoot elongation; defense responses; flower induction; leaf senescence; flower fading; abscission (separation of leaves, flowers, and fruits from the plant); and fruit ripening. In postharvest technology, ethylene is widely used for accelerating ripening of fruits. But this same simple gas is also a major cause of postharvest losses, through: undesirable acceleration of ripening; flower senescence, or leaf yellowing; initiation of undesired defense responses (leading, for example, to bitterness in carrots, and russet spotting in lettuce). In recent years there have been exciting advances in our ability to harness and control the effects of ethylene, but some significant challenges remain. In this article, I review these advances, and suggest needs for future research and development.

**Ethylene in ripening**

The use of ethylene for ripening fruits is as old as the history of agriculture. Early farmers discovered that mature, but unripe, fruit could be ripened quickly by holding them in a terra-cotta pot with a few ripe fruit. The discovery that the active agent in this process was ethylene was the basis for development of the technology that is now so widely used to de-green citrus and ripen a wide range of fruits. In recent years, ripening technology has been greatly improved by the introduction of forced-air ripening, and systems for monitoring and control of $CO_2$ levels in the ripening chamber. A major impediment to accurate control of ripening has been the lack of inexpensive and sensitive instrumentation to monitor concentrations of ethylene in the ripening room. Inexpensive infrared gas analyzers that allow monitoring of ethylene at the concentrations used in ripening (1 to 100 ppm) are now commercially available, and will surely be a standard part of ripening room technology within a few years.

The modern ‘Dwarf Cavendish’ banana is a fruit that is ideally suited to the use of ripening room technology. The fruit can be harvested mature but unripe, transported to destination markets, and then ripened, as needed using application of ethylene. The enormous success of modern commercial banana handling is due to the physiological characteristics of this cultivar. Unlike many other bananas, ripening ‘Dwarf Cavendish’ fruit produces very little ethylene, so that the presence of an occasional damaged or ripening fruit in a box does not lead to premature ripening of other fruits in the load. In this respect, 'Dwarf Cavendish' is different not only from other bananas, but also from many other fruits. Our ability to provide high quality avocados, papayas, kiwifruits, and a host of other fruit would be greatly improved if we could develop cultivars with these same physiological characteristics. Recent advances in molecular biology have provided an indication of the possibilities of this strategy.

The synthesis of ethylene in plants is dependent on a key substrate, aminocyclopropane- 1-carboxylic acid (ACC) and two key enzymes, ACC synthase, and ACC oxidase. Molecular biologists have isolated the genes that code for these two key enzymes, and have used a technology called 'anti-sense' to produce fruits where maturation proceeds normally, but ethylene synthesis is completely inhibited, so that the mature fruit require ethylene treatment for ripening. The 'Endless Summer' tomato is the first example of the use of this strategy in a commercial crop. In the future we may expect to see the technology expanded to a wide range of crops.

**Negative effects of ethylene**

Ethylene is a common air pollutant, present in smoke, and produced by internal combustion engines and ripening fruit. The deleterious effects of ethylene in fruits, vegetables, and ornamentals have been estimated to cause significant losses (as much as 10 – 20%) and tools for overcoming these losses continue to be an area for active research and development. Recent studies have suggested that many crops are affected by exposure to ethylene concentrations as low as a few parts per billion! Luckily, researchers and technologists have developed a number of new approaches to ethylene control using molecular biology, novel chemistries, and innovative technologies.

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The easiest way to prevent the effects of ethylene on perishable crops is to remove ethylene from the storage and handling environment. The tried and trusted method for achieving this is to ventilate storage rooms, packing houses and retail areas with fresh air (1 air exchange per hour) drawn from above the building where the ethylene concentration is likely to be very low. Unfortunately, tools for measuring ethylene at the concentration that may reduce quality in perishable products are expensive laboratory instruments like gas chromatographs. There is a continued need for inexpensive and sensitive tools for this purpose.

Potassium permanganate-based ethylene scrubbers are used during transport and storage of some commodities. Manufacturers continue to develop new tools for removing ethylene from the air, and we are currently testing a new unit that claims to provide a cheap and effective method for ethylene removal based on UV activation of titanium dioxide catalyst distributed on a bed of glass tubes. The manufacturers indicate 75% removal of ethylene from air passing through the unit at 30,000 cfm. If verified, these claims suggest that this unit will be a useful tool in cool storage rooms.

The isolation of the gene encoding the ethylene 'binding site', the 'trigger' for ethylene action in plants, was made possible by the isolation of ethylene-resistant mutants of a tiny weed, *Arabidopsis thaliana*. Researchers have now inserted the mutant gene into commercial crops and demonstrated that the deleterious effects of ethylene are removed. We may soon see commercialization of a wide range of ethylene-resistant ornamentals developed using this strategy. Ethylene-resistant vegetables and even fruits certainly may follow in the years ahead.

In ornamentals, too, a new gaseous chemical, 1-methylcyclopropene (1-MCP), sold in North America as 'EthylBloc' provides a tool for preventing the effects of ethylene. Treatment of flowers and potted plants with vanishingly low concentrations of this chemical (released from a powder by simply adding water) completely blocks the effects of ethylene (see Figure 1). 'EthylBloc' is already being used commercially for preventing ethylene damage and extending the life of ornamentals. Researchers are studying the possible application of 1-MCP to fruits and vegetables, where very promising results have already been reported on crops as diverse as apples, lettuce, and bananas. AgroFresh submitted a petition to the FDA for the use of 1-MCP on fruits and vegetables and a decision is expected in late 2001.