Biology of ethylene production & action

What is ethylene?
- \( \text{C}_2\text{H}_4 \)
- Very simple molecule
- A gas
- An important chemical feedstock
- A natural plant hormone

Where does ethylene come from?
- Ripening fruits
- Smoke
- Vehicle exhausts
- Ripening rooms
- Ripening fruit

Ethylene - an important factor
Useful:
- Accelerates ripening
- Causes abscission
A problem:
- Accelerates ripening
- Accelerates senescence
- Causes abscission

History of ethylene biology
- Prehistoric
  - Fruit ripening, smoky rooms, ripening fruit
- Amos, 1000 B.C.
  - Scarification of figs - wound ethylene
- Neljubow, 1907
  - Ethylene gas - plant growth regulator
- Cousins, 1913
  - Ethylene causes ripening
- Gane, 1932
  - Produced by ripening fruits
- Goeschl and Pratt, 1960
  - Role in plant growth and development
  - Plant hormone
- Veen, 1978
  - Silver thiosulfate
- Yang, 1979
  - Ethylene biosynthesis pathway
- Bleeker, 1988
  - ETR-1
- Sisler and Blankenship, 1996
  - 1-MCP
Ethylene responses

- Reduction in growth (seedlings)
- Loss of leaves and flowers (plants)
- Leaf yellowing or death (plants)
- Epinasty (leaves)
- Senescence (flowers)
- Ripening (fruits)
- Abscission (fruits, leaves, branches)
- Dehiscence (seeds)

Neljubow, a graduate student in Russia, was the first to show that ethylene caused these strange effects on etiolated pea seedlings.

Carnation model system

Characteristics of ethylene responses

- Threshold concentration (0.1 ppm)
- Plateau concentration (10 ppm)
- Associated respiration rise
- Temperature optimum (15 - 25°C)
- CO2 (>1%) inhibits

Abscission of snapdragon flowers in response to ethylene shows a typical threshold and plateau response.
Respiration - important physiological indicator

- **Non-climacteric fruits**
  - Respiration falls steadily throughout development
  - Ethylene not involved in ripening
  - Citrus, grapes, olives, cherries, many berries

Respiration and ethylene production rise during fruit ripening

**Ethylene as a ripening ‘trigger’**

- Once ripening is initiated, climacteric fruits produce ethylene
- Ripening is then self-controlled

Tools for working with ethylene: Measurement

- Expensive, but routine
- Bioassay - cheap, difficult
- Kitagawa tubes - $2 / measurement
- Proprietary analyzers - $500 - $1000
- Gas chromatograph - $10,000 - $30,000
- Photo-acoustic detector - $50,000

Sensorsense Photoacoustic Ethylene Detector - $45,000
Tools for working with ethylene: Application

- Ripening fruits
- Ethylene gas  
  Gas, closed space
- Acetylene, CO
- Ethephon
  - Liquid, spray, drench

Uses of ethylene in horticulture

- Induction of flowering
  - Bulbs, Pineapple & other Bromeliads
- Harvest aid
  - Walnuts, Sour cherries
- Induction of ripening or coloring
  - Bananas, Citrus

Ethylene biosynthesis

\[
\text{Methionine} \rightarrow \text{SAM synthesize} \rightarrow \text{SAM} \\
\text{ACC synthesize} \rightarrow \text{S-adenosyl methionine} \\
\text{ACC} \rightarrow \text{1-aminocyclopropane-1-carboxylic acid} \\
\text{ACC oxidase} \rightarrow \text{Ethylene}
\]
The Yang Cycle

Ethylene → ACC oxidase → S-methyl thioribose → SAM synthase → MET

Low O₂ → ACC oxidase → S-methyl thioadenosine → ACC synthase → AVG/AOA

Molecular manipulation of ripening

- Anti-sense ACC synthase
- Anti-sense ACC oxidase
- Result - fruits that ripen very slowly, require ethylene treatment to ripen
- Just like Never Ripe (NR), a tomato mutant, used to develop long shelf-life tomatoes

Anti-sense ACC oxidase in melons

3 months after pollination (i.e. 1.5 months after harvest)

Deleterious effects of ethylene

- Plants
  - Growth distortion
- Leaves
  - Yellowing, abscission, necrosis
- Flowers
  - Senescence, abscission
- Fruits
  - Ripening, softening

Anti-sense technology will improve marketing of many fruits
Overcoming ethylene effects

- Avoidance
- Removal
- Inhibition of production
- Inhibition of action
- Germplasm selection/engineering

Avoidance

- Keep ethylene sources away from sensitive products
  - Electric fork-hoists, floor polishers

Removal

- Ventilation – 1 air exchange per hour with fresh air
- Chemical oxidation
  - $\text{KMnO}_4$
- Oxidation with UV lamps
Inhibition of ethylene action

- Controlled and modified atmospheres
  - Low oxygen, high CO₂ inhibit production, action
- Silver thiosulfate
  - Registered for cut flowers
- Cyclopropenes
  - 1-MCP
  - Registered for many crops

1-MCP - a gaseous ethylene inhibitor

EthylBloc sachets in shipping boxes

Photos: George Staby
Already in use to extend life of fruits and vegetables

Avoiding ethylene effects
- Selection of ethylene-resistant germplasm

Avoiding ethylene effects
- Understanding ethylene action
- Biotechnology to interfere with the action cascade

Mechanism of ethylene action
Biotechnology!

Use of the ethylene receptor gene

- Insert mutated gene in sensitive plant - becomes insensitive
- Use tissue-specific, or stage-specific 'promoter' - ethylene action is inhibited only in that tissue or at that time (e.g. mature flowers, ripe fruits)
- Already done with petunias, carnations

New technology – use inducible promoters

- Application of a simple chemical or physical stress
  - Alcohol, dexamethasone, copper, heat
- Drives synthesis of a gene
  - For example, DEX/etr1

Questions?