



Current and Potential Commercial Applications of the Suppression of Ethylene Action by 1-MCP in Plants

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Ancient history of the commercial impact of ethylene in fruit production



What the ancients understood...

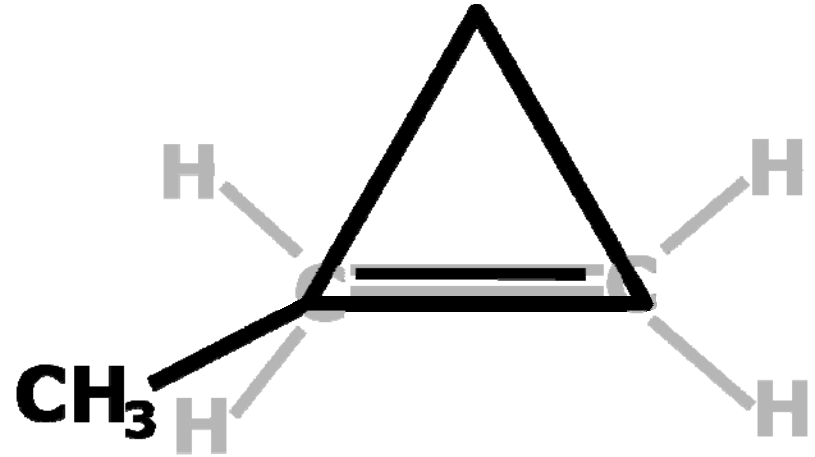
- § 'Gashing' figs stimulated ripening
 - § Managing storage temperature kept fruit fresher
 - § Many fruits need air circulation during storage
- Many of these concepts are still in use*

Modern 'history' of ethylene management

- **Mid-1990's**
 - Ed Sisler (NCSU) and co-workers identify a number of compounds that inhibit ethylene action
 - 1-MCP (1-methylcyclopropene) is the most active
 - Sisler and Sylvia Blankenship (NCSU) receive 1st patent
- **Late 1990's**
 - Rohm and Haas licenses patents from NCSU
 - In 1999, Rohm and Haas forms AgroFresh
- **2002**
 - AgroFresh commercializes 1-MCP for apple storage
 - Other commercial applications of ethylene management with 1-MCP start to be considered

1-MCP and AgroFresh formulations

- 1-MCP is very similar to naturally occurring ethylene

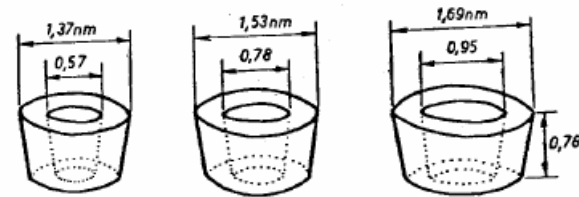
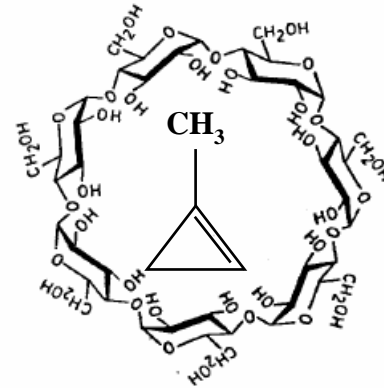


1-MCP and AgroFresh formulations

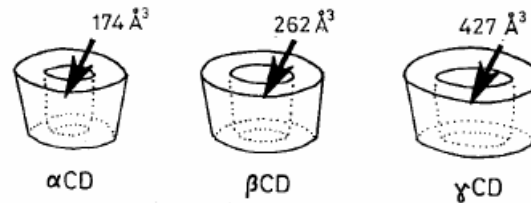
- 1-MCP is very similar to naturally occurring ethylene
- Innovation: 1-MCP is stabilized in an α -cyclodextrin 'donut'
- Stable when dry; 1-MCP is released upon wetting

Chemical Reviews, 1998, Vol. 98, No. 5 1745

H₂O

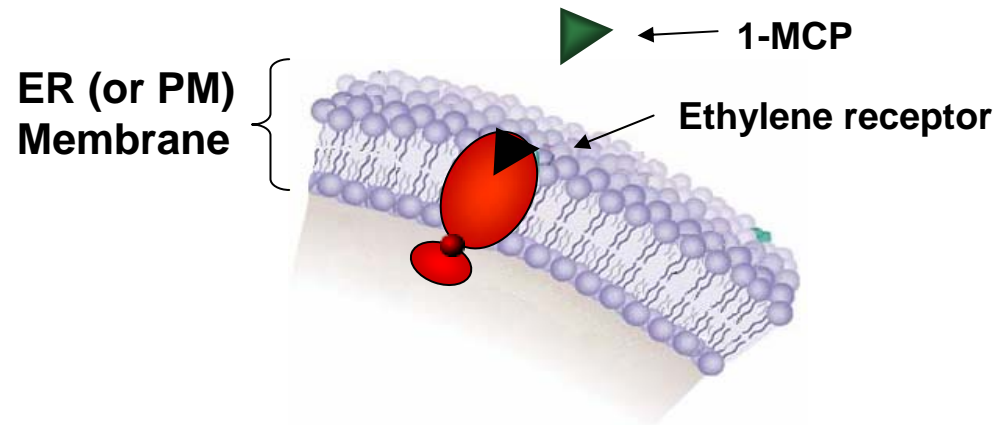


CAVITY VOLUME:



1-MCP and AgroFresh formulations

- Very similar to naturally occurring ethylene
- Innovation: 1-MCP is stabilized in an α -cyclodextrin 'donut'
- Stable when dry; 1-MCP is released upon wetting
- A competitive inhibitor of ethylene receptor binding
 - Receptor has a 10x higher affinity for 1-MCP than for ethylene
 - Suppresses ripening- and stress-related genes



AgroFresh Intellectual Property

AgroFresh holds exclusive global licensing rights from North Carolina State University

Patents Issued: 14 Patents Pending: 18

- Use, manufacture, formulations, and delivery systems for 1-MCP and all possible analogs

Acquired Floralife, Inc. in 2006

Multiple Trademark/Service Marks

AgroFresh Brands



Negative effect of ethylene	Benefit of blocking ethylene action with 1-MCP
Promotes ripening; particularly climacteric fruits	Improves storage life and maintains consumer quality
Stimulates senescence of floral organs	Increases vase life and reduces transportation losses
Triggers fruit drop in orchard crops	Improves harvest labor management
Stimulates ovule/fruit abortion and accelerates leaf senescence	Improves yield potential by reducing crop response to stress
Creates challenges for plant hormone researchers	Provides an excellent tool for basic & applied research

AgroFresh Brands



More than 80 comprehensive studies indicate favorable tox and eco-tox profiles for the formulation of 1-MCP



1-MCP is registered in 27 countries on more than 25 different crops



First pre-harvest hort and agronomic registrations approved in 2007





A Global Success Story:

The SmartFreshSM Quality System



- Highly regarded for maintaining the quality of a wide variety of fruits and vegetables;



- Today, more than 50% of all apples in the U.S. are SmartFresh quality apples



- Key benefit in apples

- SmartFreshSM Quality Apples have a firmness 2 – 4 pounds higher than untreated control after 14 days at room temperature





The SmartFresh System™ for Commercial Storage Rooms: Safe & Simple

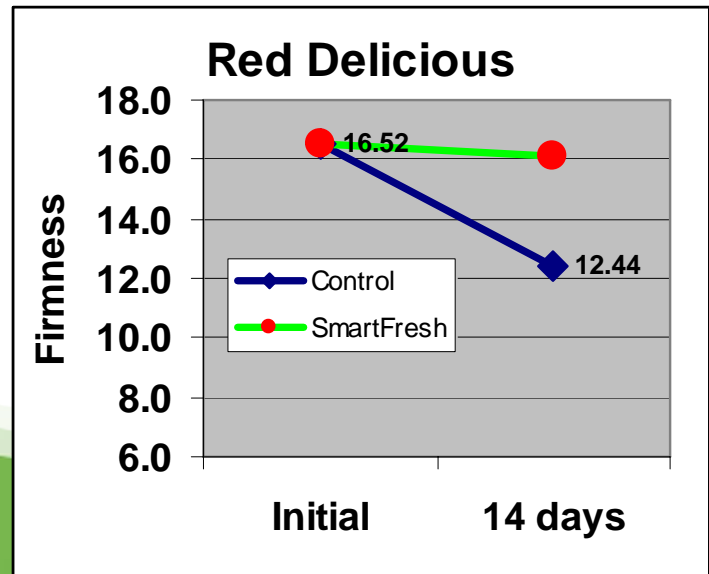
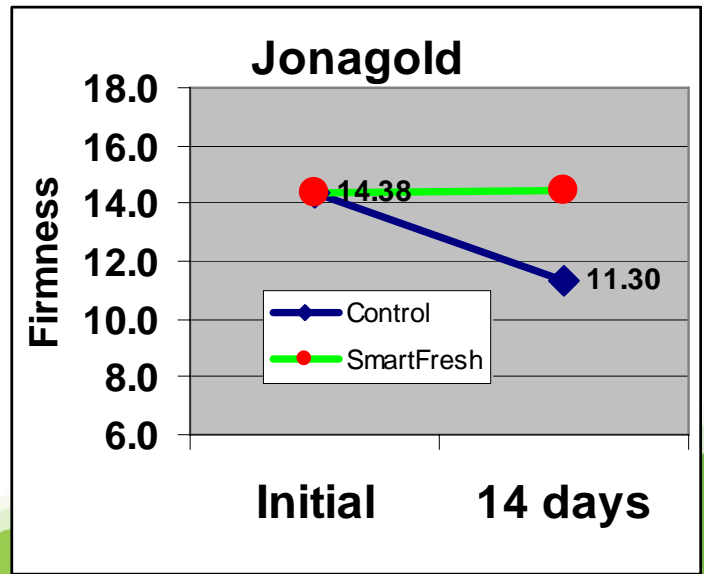
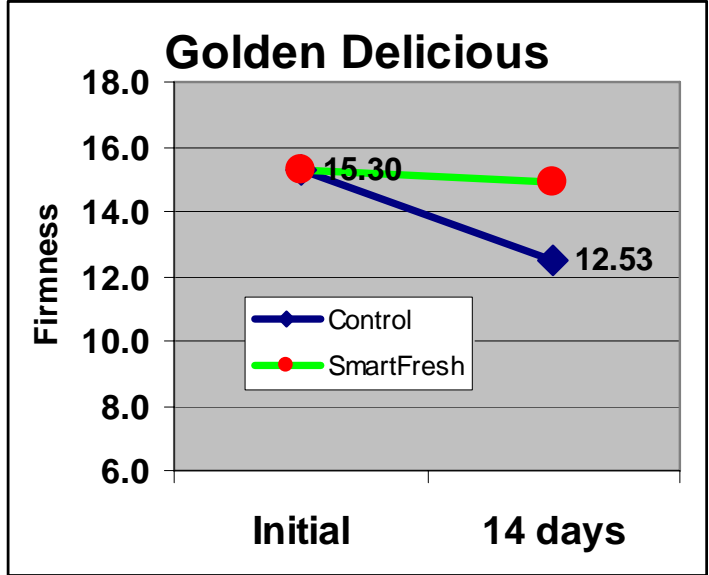
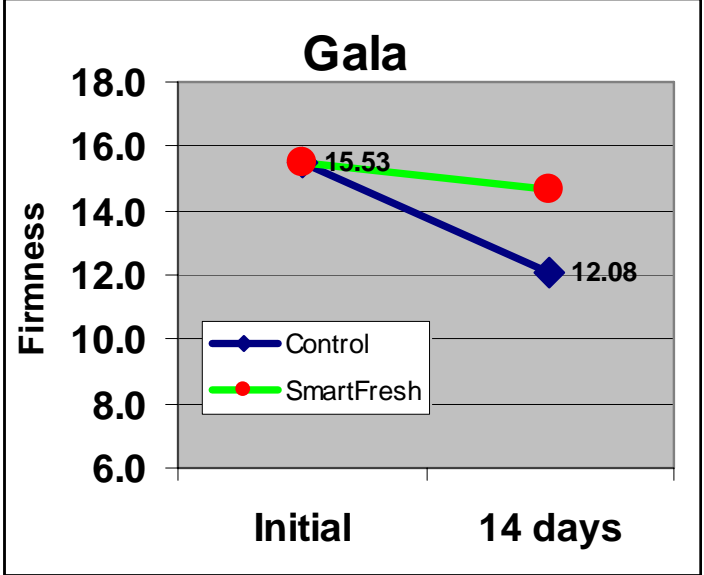
1-MCP
complements
existing
technologies

is highly active
at
very low
concentrations





Results of tests on 25,000 samples of **SmartFreshSM** serviced apples* compared to the controls. Apples from storage were kept at room temperature for 14 days.



2-3# can be the difference between crispy and mushy!

Factors influencing success in apples and other fruits

1. Genotype
2. Pre-harvest environmental conditions
3. Physiological age of the fruit
4. Treatment conditions
5. Post-harvest storage conditions
6. Impact of the treatment on pathological/physiological disorders

Source: Sozzi & Beaudry (2007)

This type of information is needed to define and refine use recommendations in each crop

Flowers and Ornamentals

EthylBloc (1-MCP) can reduce:

- Senescence or 'sleepiness'
- Petal abscission or 'shattering'
- The rate of flower opening

Benefit:

- Reduces losses in-transit and in-store
- Extends the vase life and marketability of cut flower, flowering potted plants and bedding plants



EthylBloc[®]
ethylene guard

Flowers and Ornamentals

- Ethylene has been reported to contribute 30% of all total post harvest dumpage in horticulture crops
- 1-MCP protects from both internal and external ethylene sources – unlike AOA and AVG



Lower temperatures require adjusted EthylBloc (1-MCP) exposure times



Harvista – In-field application of 1-MCP



- *AgroFresh scientists discovered that 1-MCP can be delivered using commercial spray systems*
- **Controlling ethylene production in the orchard:**
 - 1) **Reduces fruit drop**
 - 2) **Maintain fruit firmness on the tree**
 - 3) **Allows time for additional fruit growth and color development**
 - 4) **Eases labor and scheduling of harvest crews**



Harvista

Managing Fruit Drop in Pears

17 days after application



Untreated Control

Harvista (1-MCP)

applied 7 dbh

J. DeEll, OMAFRA - 2006

BARTLETT
PEARS: Harvista
reduces fruit
drop, extends
harvest period
and fruit quality

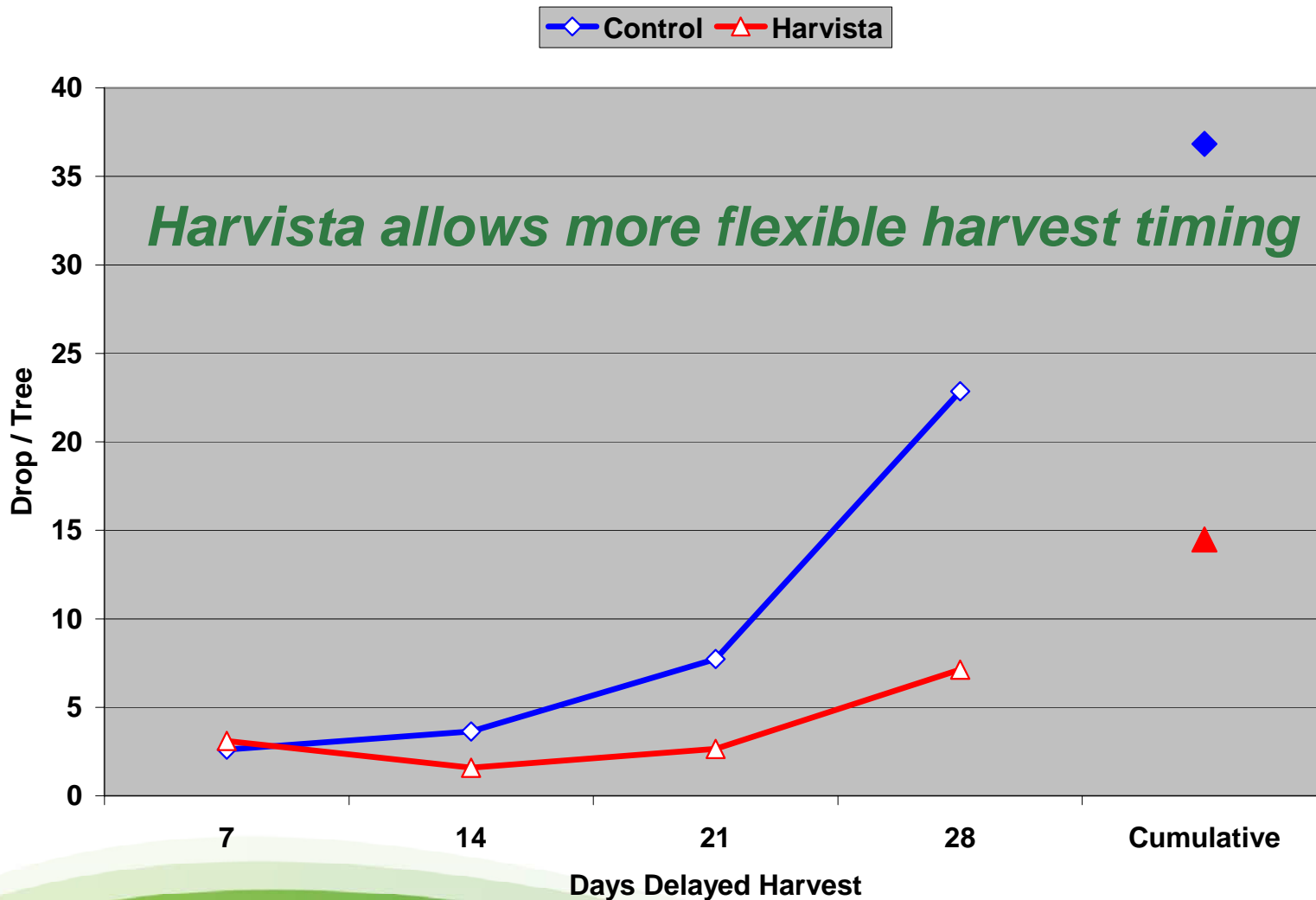
fruit dropped

<i>HC1: 9/3</i>	<i>H2: 9/13</i>	<i>H3: 9/20</i>
Control	130	515
50 mg/l	19	274
100 mg/l	86	166



Harvista - Golden Delicious - Fruit Drop

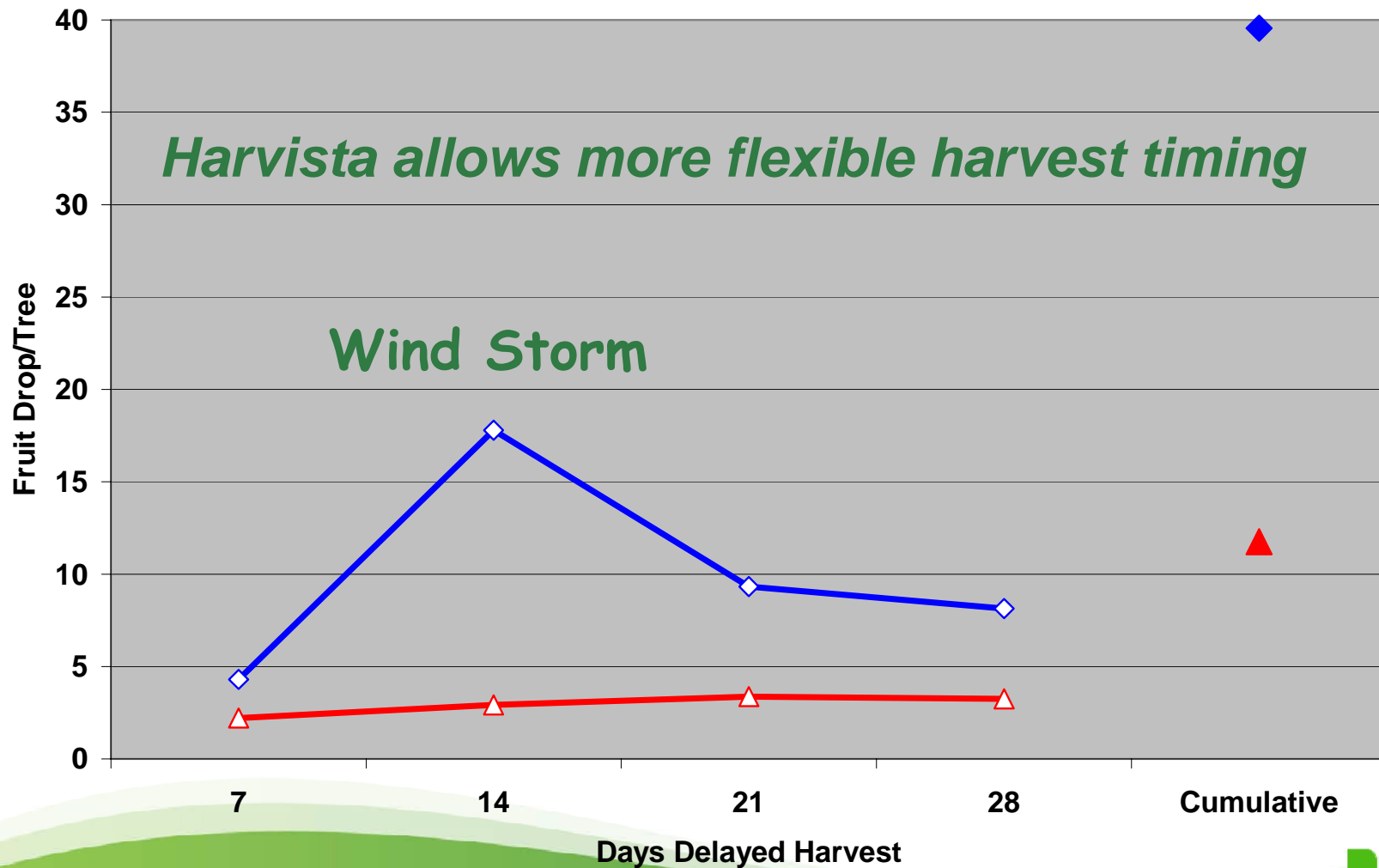
75 mg/l applied 7 days prior to commercial harvest



Harvista - Red Delicious - Fruit Drop

75 mg/l applied 7 days prior to commercial harvest

Control Harvista



1st Grade
>95% blush

2nd Grade
47-95% blush

3rd Grade
4-47% blush

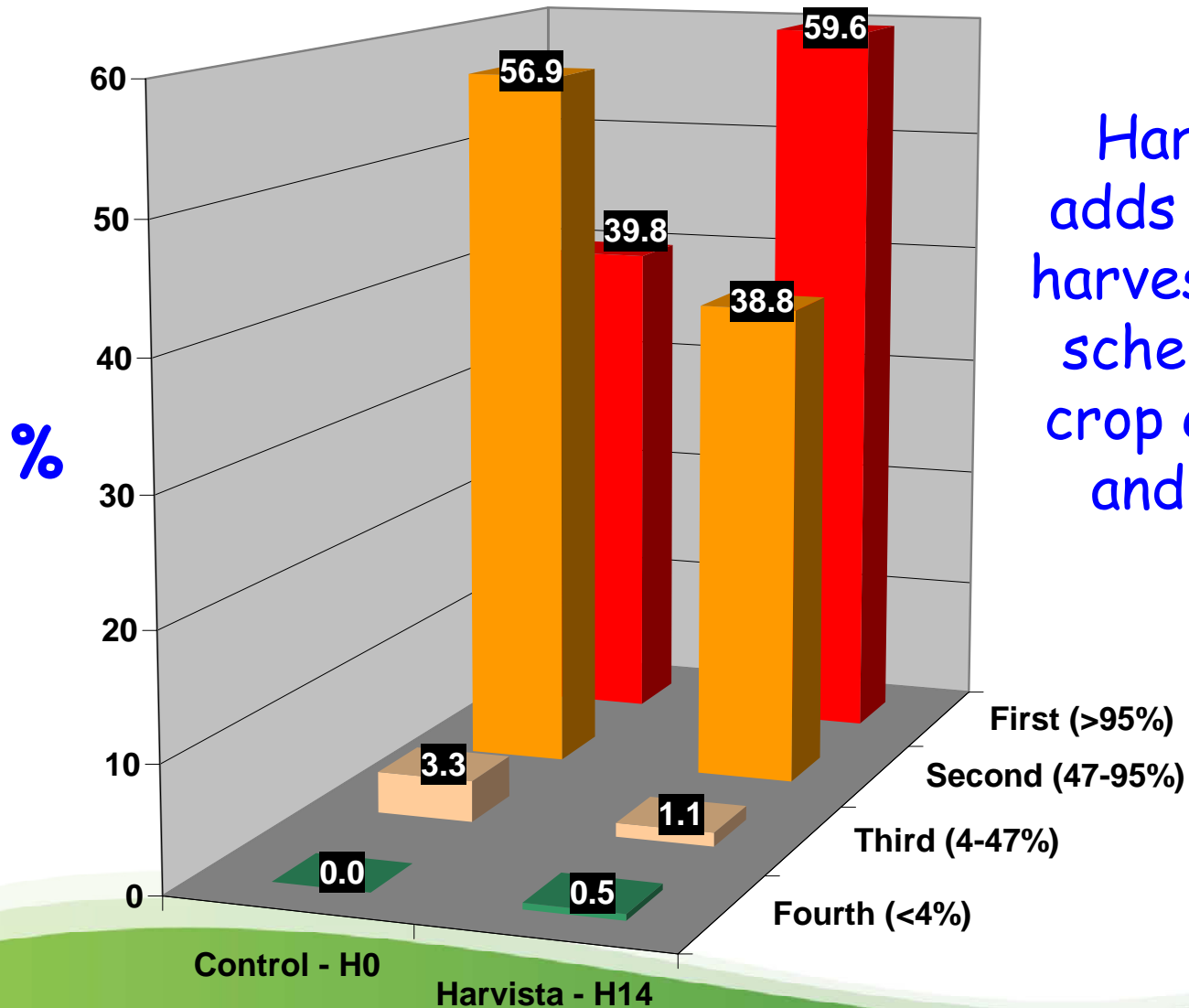


Red Delicious Color Grades

Harvista - Red Delicious Color

14 Day Delayed Harvest

75 mg/l applied 7 days prior to commercial harvest



Harvista
adds value -
harvest labor
scheduling,
crop quality,
and yield



Invinsa™

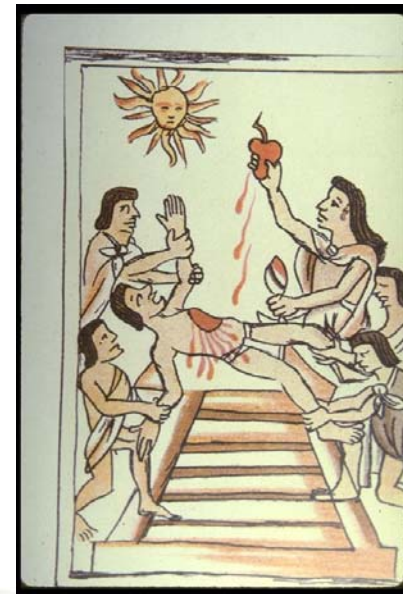
Crop Stress Protection

How Invinisa (1-MCP)
works
in field crops



Ancient history of managing stress in agronomic crops

- Example: Corn (Maize)
 - Aztecs recognized that water stress and heat could reduce their corn yields
 - To avoid the negative impact of these stresses, they:
 - conducted human sacrifices

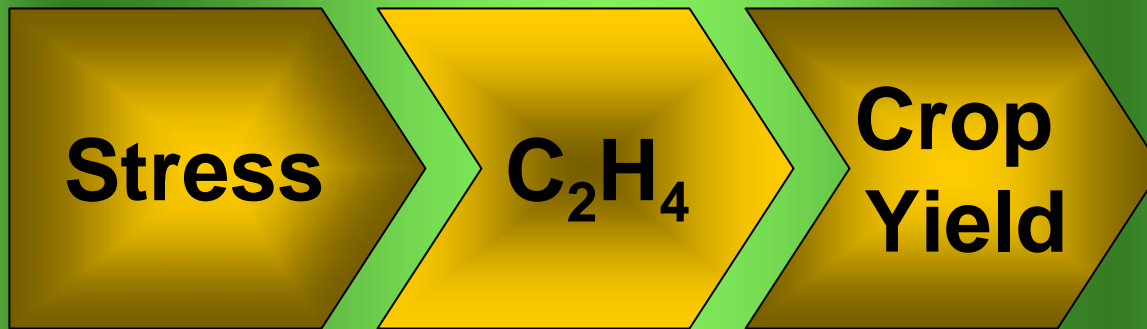


Ancient history of managing stress in agronomic crops

- Example: Corn (Maize)
 - Aztecs recognized that water stress and heat could reduce their corn yields
 - To avoid the negative impact of these stresses, they:
 - conducted human sacrifices
- **This is NOT the direction that AgroFresh has taken with ethylene management in agronomic crops**



We knew that there were links between:



Which plants?

When?

Where?

Why?

How?

What types of stress induce ethylene?



Stress

- Drought Stress
- High Temperatures
- Shading (high plant populations)
- Nutrient Deficiency
- Biotic stresses? others?

Stress-induced ethylene reduces grain and fiber yield

Food 'Source' Effects:

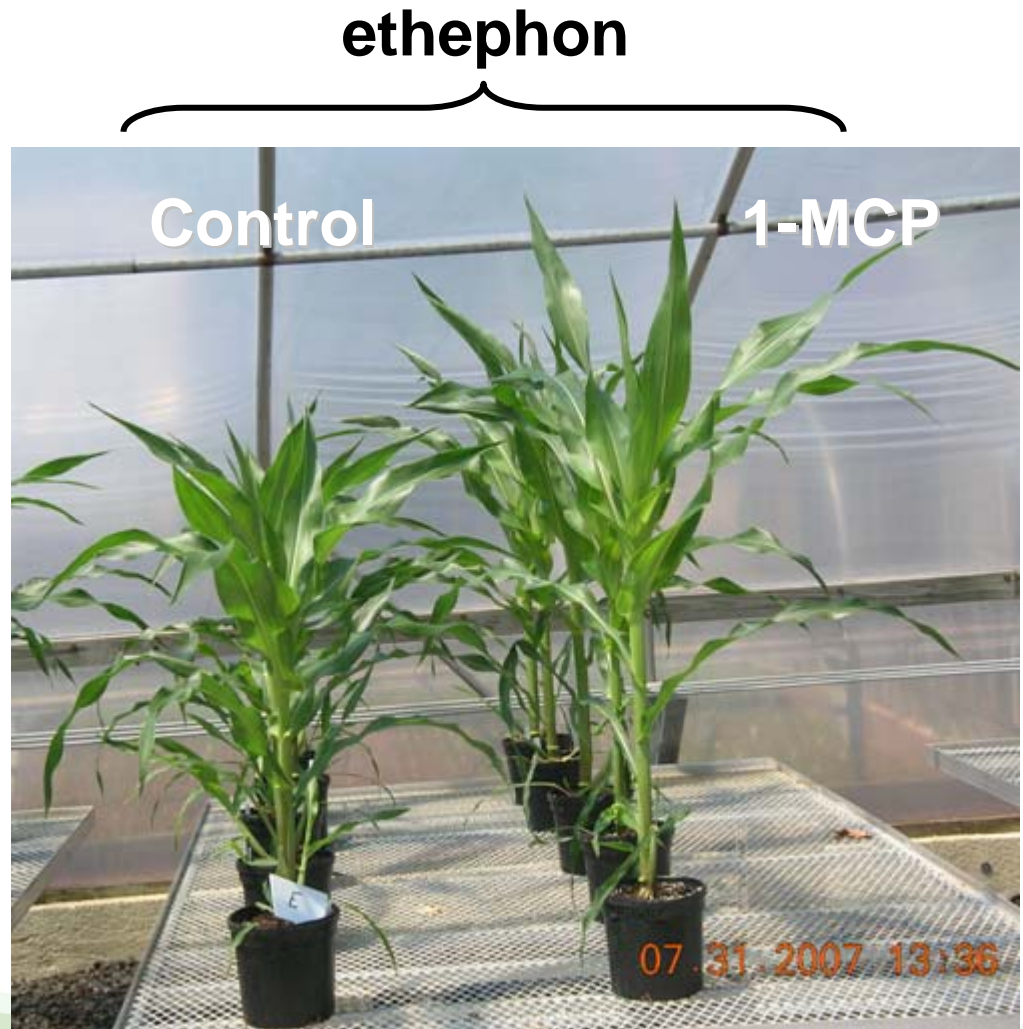
- Reducing duration of active photosynthesis
 - Inducing premature leaf senescence
 - Inducing premature leaf abscission
- Reducing PS efficiency

Storage 'Sink' Effects:

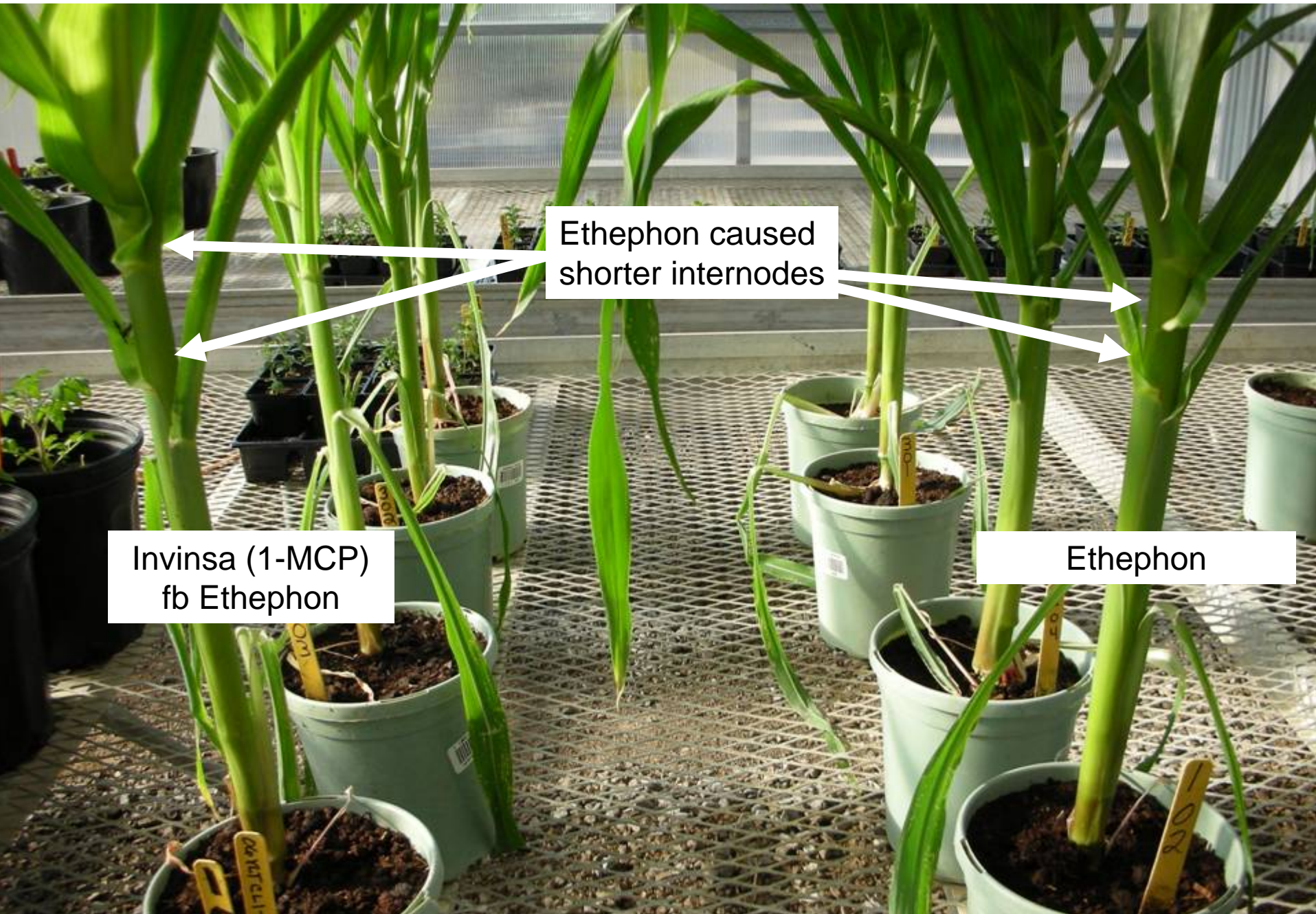
- Reducing number of reproductive units
 - Inducing flower and ovule abortion (pre-fertilization)
 - Inducing fruit and seed abortion (post-fertilization)
- Limiting the potential size of reproductive structures
 - Inducing premature endosperm programmed cell death

Does 1-MCP work in corn?

- Corn response to 1-MCP (25 g ai/ha) followed by ethephon
 - 1-MCP prevented ethephon-induced height reduction



Invinsa prevents ethephon-induced internode shortening



Ethephon caused shorter internodes

Invinsa (1-MCP)
fb Ethephon

Ethephon

Invinsa (1-MCP)

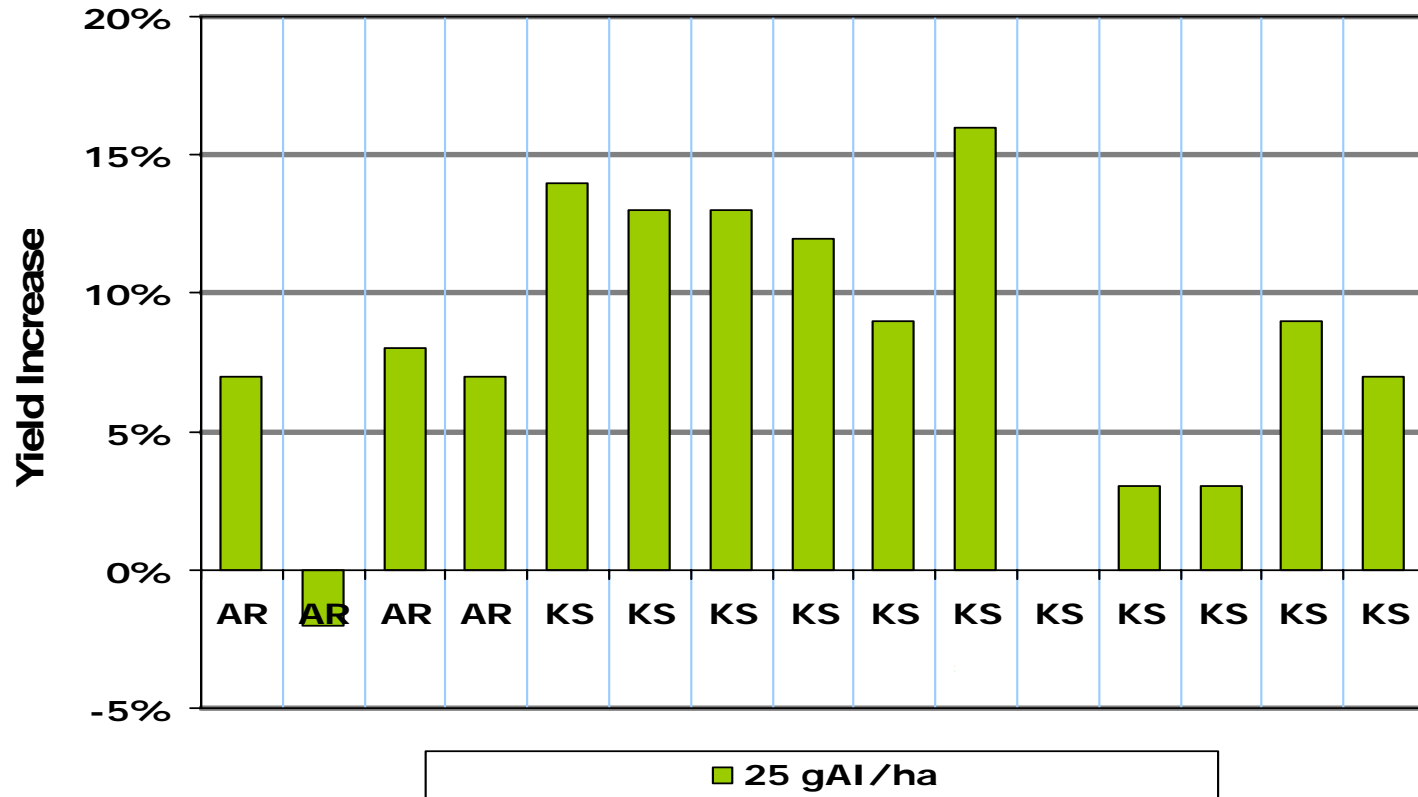
Observations - US & Latin America

- **Corn responses to Invinsa**
 - 25 g ai/ha; V5, V10, V15, & VT
 - Continued internode elongation during drought
 - Reduced leaf curling (heat/drought; differences transient)
 - Delayed leaf senescence lower leaves
 - Increased ear length and %fill
 - Increased grain yields



2006 US Corn Trials

Invinsa improves heat stress tolerance

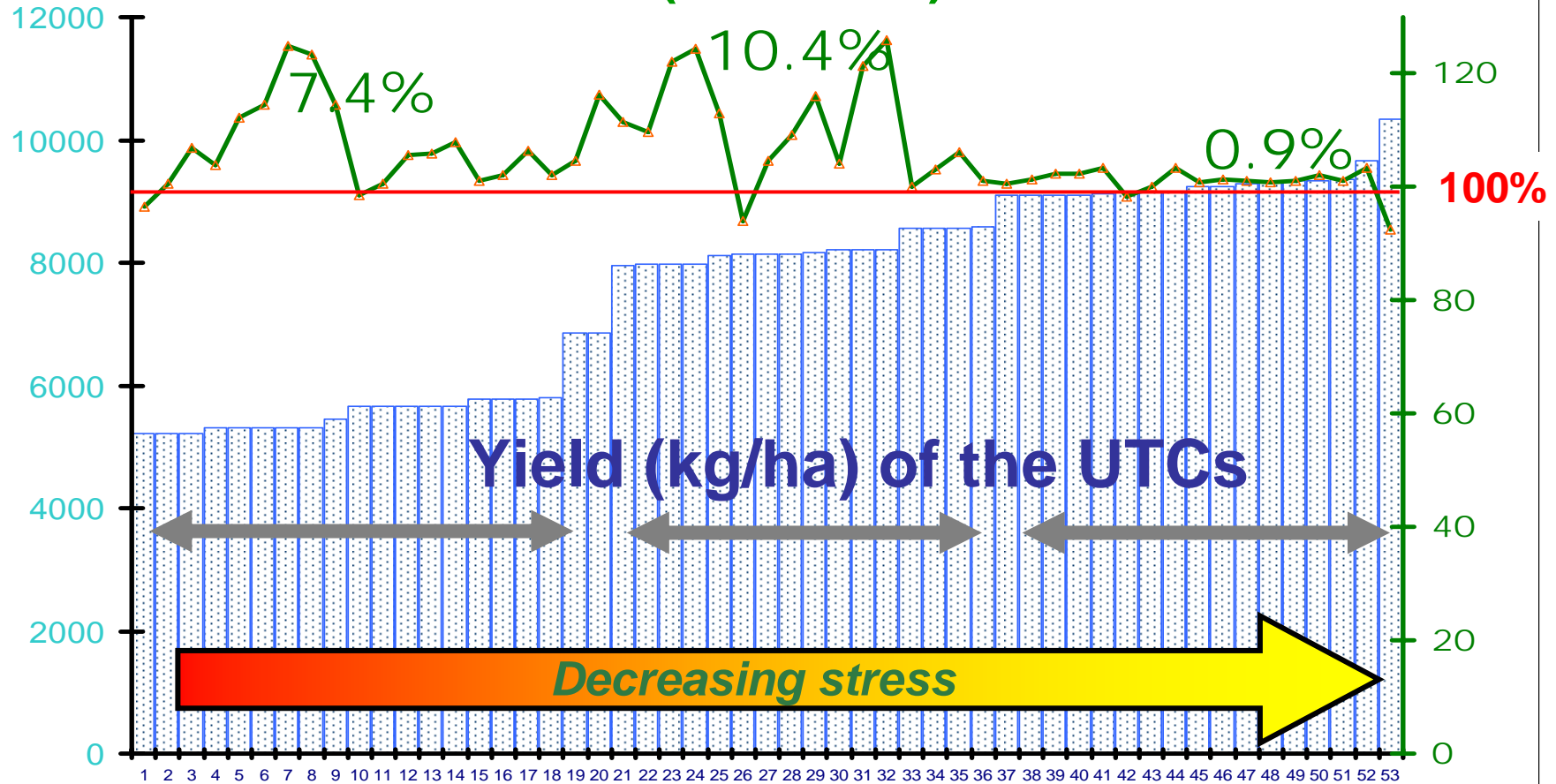


Field trials conducted in numerous environments across the US in 2006
V10 application timing: increased corn yield under heat stress conditions

Corn Small Plot Summary

Argentina 2007 Invinsa @ 25 g/ha

Yield increase (% of UTC) from Invinsa



Invinsa had greater effects in fields with moderate stress

Similar results in other crops...

Potential benefits resulting in yield increase

- **Soybean:**
Improves flower and pod retention and delays premature senescence due to stress; increases seed yield
- **Cotton:**
Improves flower and boll retention; increases fiber yield and quality
- **Wheat:**
Improves stress tolerance, increases kernel weight and number

Many questions remain...

Research objectives – work underway

- Characterize linkage between stress and ethylene – impact on yield components
- Relate performance to stress, developmental stage, and genotype
- Focus on isolating specific stress conditions and quantifying the Invinsa technology benefit—heat, drought, population, fertility, etc.
- Further refine application recommendations

Potential for collaborations

- 1-MCP offers a broadly applicable way of inhibiting the perception of ethylene with proven commercial value
- To continue this record of success, more knowledge regarding the role of ethylene in plants is needed
- AgroFresh is open to considering your interests in research collaborations
- Several tools for ethylene management in lab and field research are available through Material Transfer Agreement

Summary:



SmartFresh



- Ethylene impacts many commercially-significant processes in plants – horticultural, floricultural, and agronomic
- 1-MCP can deliver commercial value through managing these processes
- Additional research will be needed to optimize these benefits across more crops and conditions



Harvista





Thank you.

Questions?