7^{th} Lecture, Pathology

Principles of Postharvest Plant Disease Management

Prevention of diseases development: cultural, sanitizers and induce resistance

Cultural and environmental management

1) Use of resistant varieties;
2) Avoiding field conditions that are conducive to high populations of fruit decay pathogens;
3) Keeping plants vigorous and avoiding fruit senescence;
4) Carefully managing water sources and possible contamination in the field;
5) Minimizing the potential for fruit inoculation during harvest and handling and
6) Creating a postharvest environment that is unfavorable for decay development.

Principles of Plant Disease Managment

- **<u>Preventive</u>**

  - **Avoidance of the pathogen (cultural practices)**
  - **Eradication (Elimination or reducing inoculum, Sanitation)**
  - **Induce resistance (Hormonal, Chemical or biological).**

Preventive control: avoidance of the pathogen

- Field sanitation
- Sanitation of store rooms by spray or gassing

Preventive control: avoidance of the pathogen

- **Field sanitation :**
  - **Presence of decayed tissue**
  - **Presence of spores in store rooms**

Field and store room sanitation

Decayed fruits

Citrus groves with fruits with *Penicillium digitatum*

Nectarines groves with last years infection of *Monilinia*


gettyimages


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Decayed fruits

Field and store room sanitation

Decayed fruits

Citrus groves with fruits with *Penicillium digitatum*

Nectarines groves with last years infection of *Monilinia*

Decayed tissue

Release of flower remnants of kiwi fruit infected with *Botrytis*

Sanitation and windows opening of kiwi orchards




Field and store room sanitation

Decayed fruits

Citrus groves with fruits with *Penicillium digitatum*

Nectarines groves with last years infection of *Monilinia*

Decayed tissue

Release of flower remnants of kiwi fruit infected with *Botrytis*

Infected soil

Remnants of infected fruits affected with *Mucor piriformis*

Infected fruits with Mucor in soil of Washington State orchards (USA, Italy)

Field and store room sanitation

Decayed fruits

Citrus groves with fruits with *Penicillium digitatum*

Nectarines groves with last years infection of *Monilinia*

Decayed tissue

Release of flower remnants of kiwi fruit infected with *Botrytis*

Infected soil

Remnants of infected fruits affected with *Mucor piriformis*

Bin with remnants of remnants of decayed fruits

Remnants of decay nectarines fruits may contribute to infection of new harvested nectarins

Sanitation strategies of harvest and storage bins before re-use

This include:

- Disinfection, sanitation of bins before use in the filed
- Disinfesation of storage rooms

Sanitation before sending to the orchard

Sanitation at the field!!

Sanitation of empty store rooms

Store room sanitation

Treatments with the following compounds:

SO_2

Ozone

Chlorine

$KMnO_4$

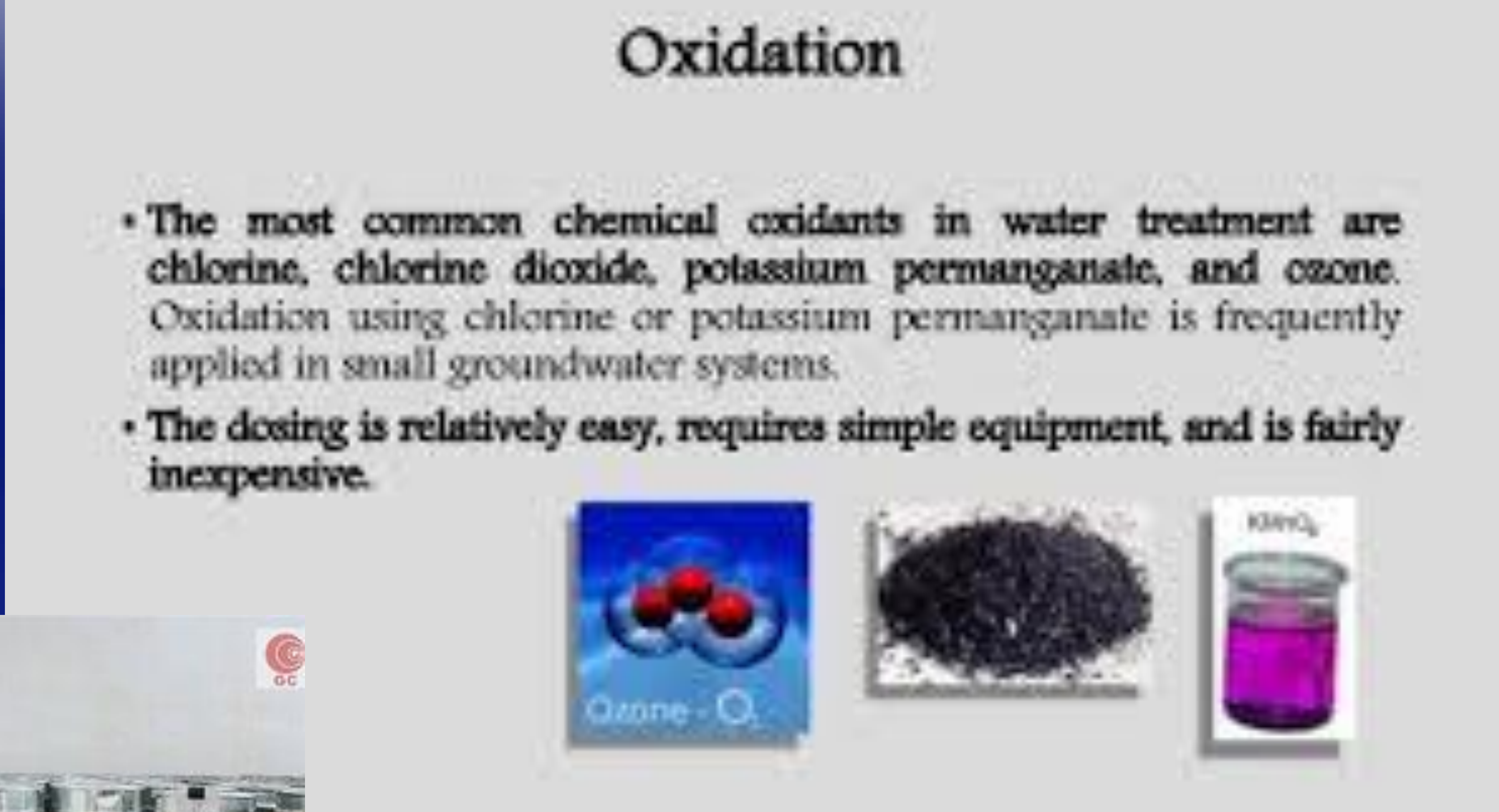
Formaldehyde

Isopropyl-alchohol

Quaternary ammonium compounds

SO_2 dispenser

Chlorine dioxide



Formaldehyde
formalin

- Formaldehyde is used as a disinfectant and sterilants in both its liquid and gaseous states.
- The aqueous solution is a bactericide, tuberculocide, fungicide, virucidal and sporicidal.

- ***Mode of Action.*** Formaldehyde inactivates microorganisms by alkalizing the amino and sulfhydral groups of proteins and ring nitrogen atoms of purine bases.

- **Be careful in handling Formaldehyde, wear mask (irritant and potential carcinogenic)**

Chemical Agents: Quaternary Ammonium Compounds

- Quaternary ammonium compounds are cationic detergents
- Amphipathic molecules that act as emulsifying agents
- Denature proteins and disrupt membranes
- Used as disinfectants and skin antiseptics
- Examples: cetylpyridinium chloride, benzalkonium chloride

Principles of Plant Disease Management
Summary of last lesson

- **<u>Preventive</u>**

  - Cultural practices: avoidance of the pathogen (cultural practices)
  - Eradication of the pathogen in the orchard and in the store room
  - Induce resistance (Hormonal, Chemical or biological).

Principles of Plant Disease Managment

- Protection/Preventive by "induce resistance by reduced ripening"

-Protection/prevention by physiological treatments (use of growth regulators)

-

Preventive Practices using growth regulators

<u>**Altering the host physiology and susceptibility**</u>

Indirect effect on the pathogen

- **Plant Growth regulators (PGRs)**

  --Gibberellin (persimmon and citrus)

  --2,4 D (Citrus)

  --Gibberellin+Cytokinin (Superlon, persimmon)

  --Ethylene biosynthesis inhibitors?
- **Effective against weak pathogens**

Treatments with growth regulators for the induction of resistance and improved fruit quality

- Treatments with GA_3 on persimmons
- Treatments with GA_3+Benzyl-Adenin on persimmons
- Effect of GA_3 on quality of onion (Chives)
- Treatments with GA_3 and 2,4-D on citrus and mango fruits

GA_3 treatments on persimmons before harvest

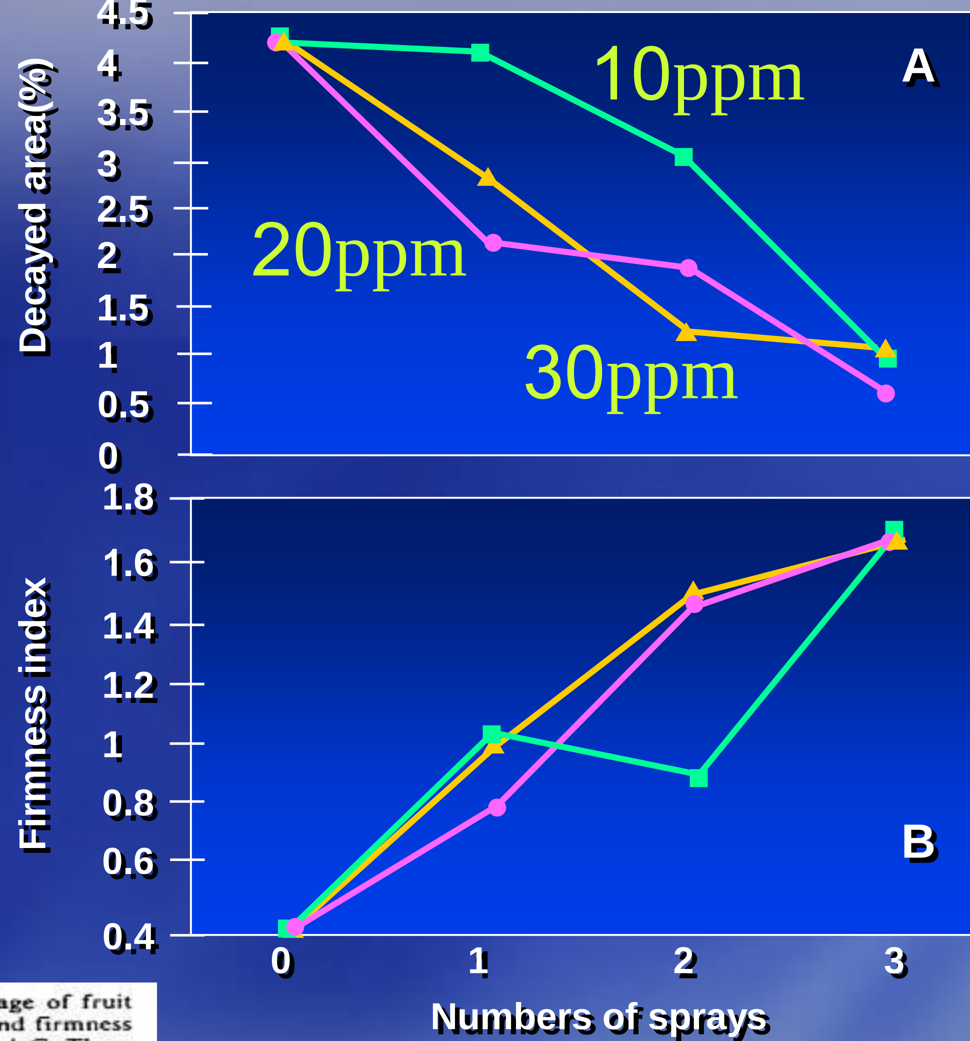


Fig. 4. Effect of GA_3 treatments before harvest on percentage of fruit surface area with lesion caused by *Alternaria alternata* (A) and firmness of Triumph persimmon fruits (B) after storage for 7 mo at −1 C. Three GA_3 sprays were applied 30, 20, and 10 days before harvest. Two-spray treatment was applied 30 and 20 days before harvest. The single-spray treatment was applied 30 days before harvest. GA_3 was applied at 10 μg/ml (■), 20 μg/ml (•) and 30 μg/ml (▲). Each point represents the average 250 fruits (50 fruit × 5 replications). Percentage of decayed area was estimated by comparison of the decayed area with diagrams of percent coverage. Index of firmness varies between 0 and 2 as described in Materials and Methods.

Effect of preharvest treatments on calyx erectness

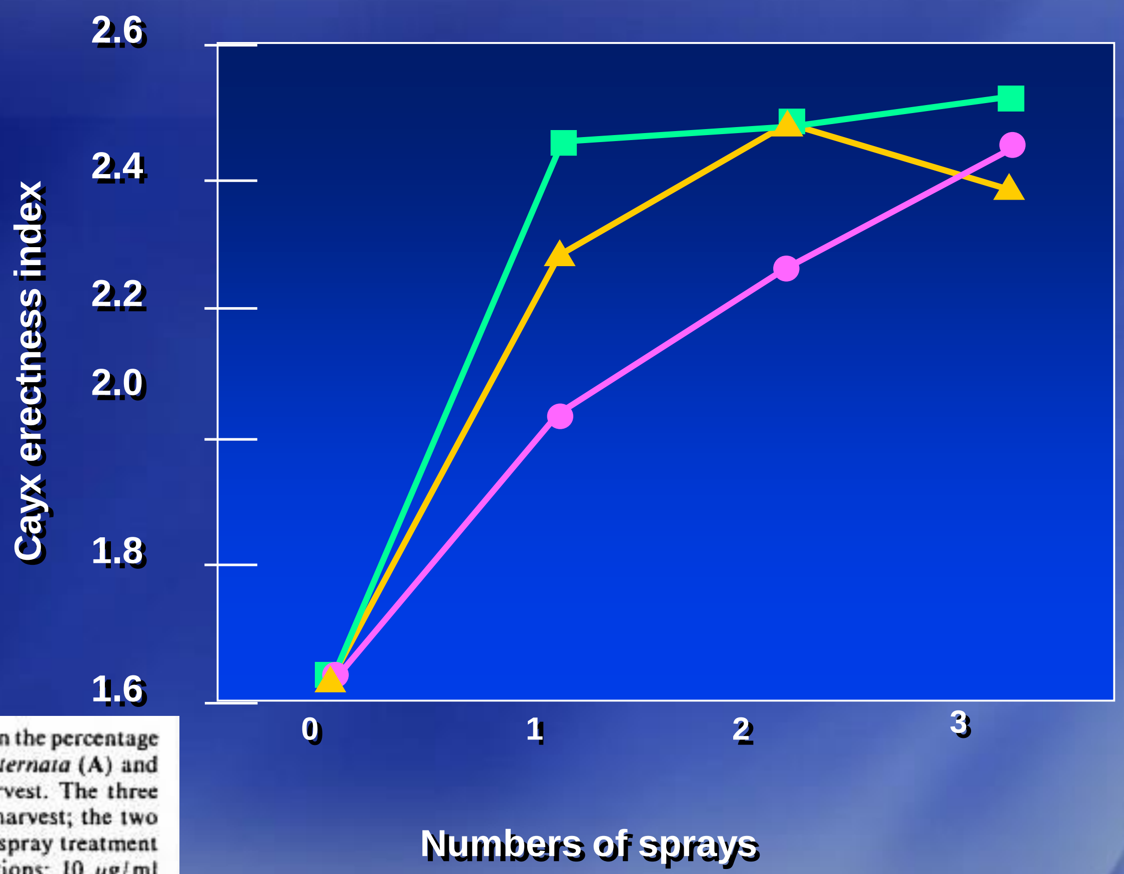
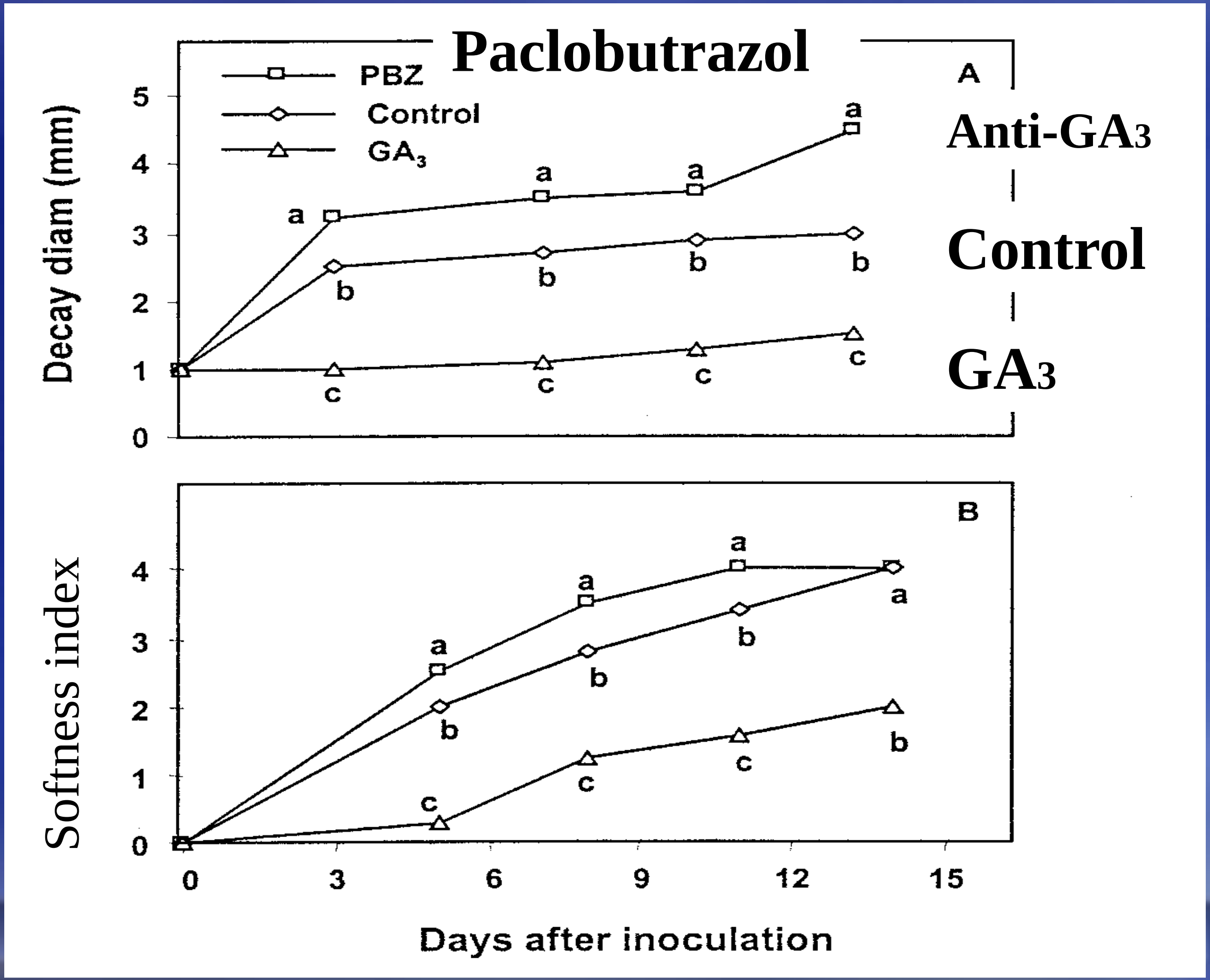


Fig. 2. Effect of GA_3 treatments during fruit development on the percentage of fruit surface area with lesions caused by *Alternaria alternata* (**A**) and calyx erectness (**B**) on Triumph persimmon fruits at harvest. The three spray treatment was applied 30, 20, and 10 days before harvest; the two spray treatment 30 and 20 days before harvest; the single spray treatment 30 days before harvest. Sprays were at three concentrations: 10 $\mu g/ml$ (■), 20 $\mu g/ml$ (*) and 30 $\mu g/ml$ (▲). Decayed area was estimated by comparison with diagrams of percent coverage. Calyx erectness varies between 0 at 4 depending on the angle between sepals and fruit according to Materials and Methods. Each point is the average of values of 250 fruits (50 fruits × 5 replications).

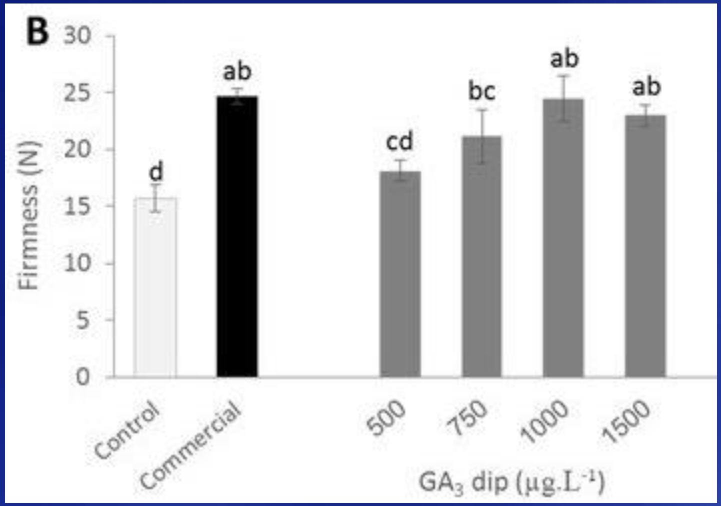

Control

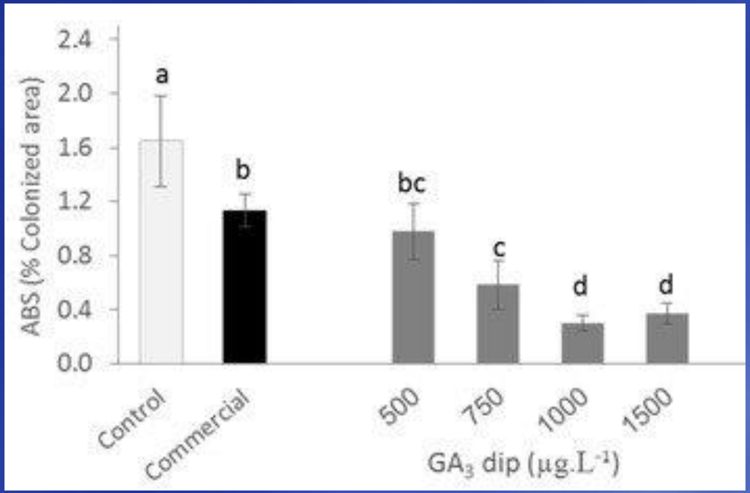

GA_3

Effect of orchard application of growth regulators on postharvest development of *Alternaria alternata* symptoms and fruit firmness in inoculated persimmon fruits incubated at 25°C



Effect of preharvest spray (commercial) and postharvest dip treatments with GA_3, on the fruit firmness, levels of Alternaria black spot on persimmon fruit. Triumph after 3 months of storage at 0 °C.





Inhibition of fruit wounds by the use of growth regulators

GA4+7 Gibberellin + BA Cytokinin = SUPERLON

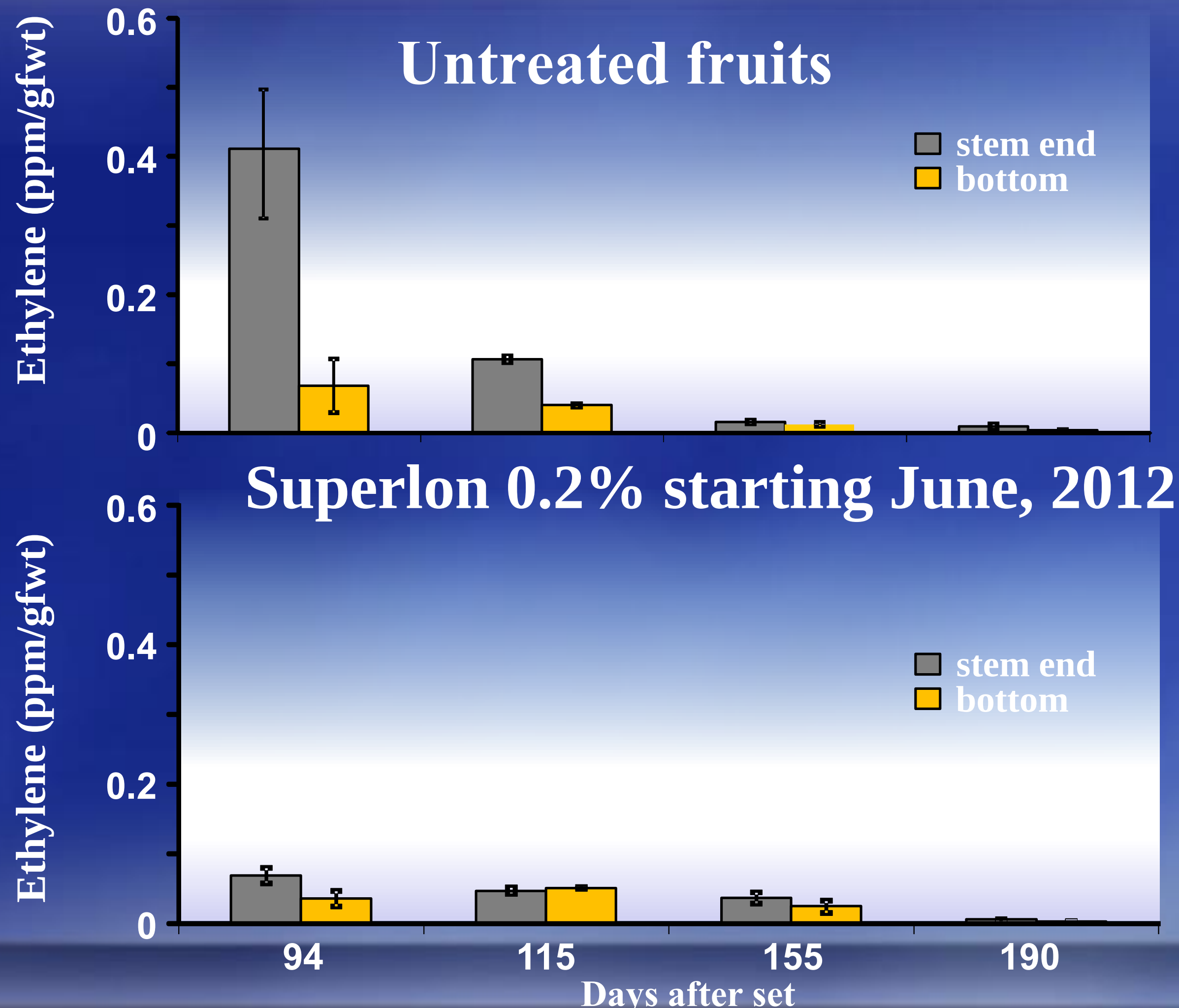
Cytokinin- growth hormone involved in cell division and cell growth

Giberellin- growth hormone involved in cell enlargement

Most of infection of Alternaria is observed in the upper part of the fruit under the fruit sepal

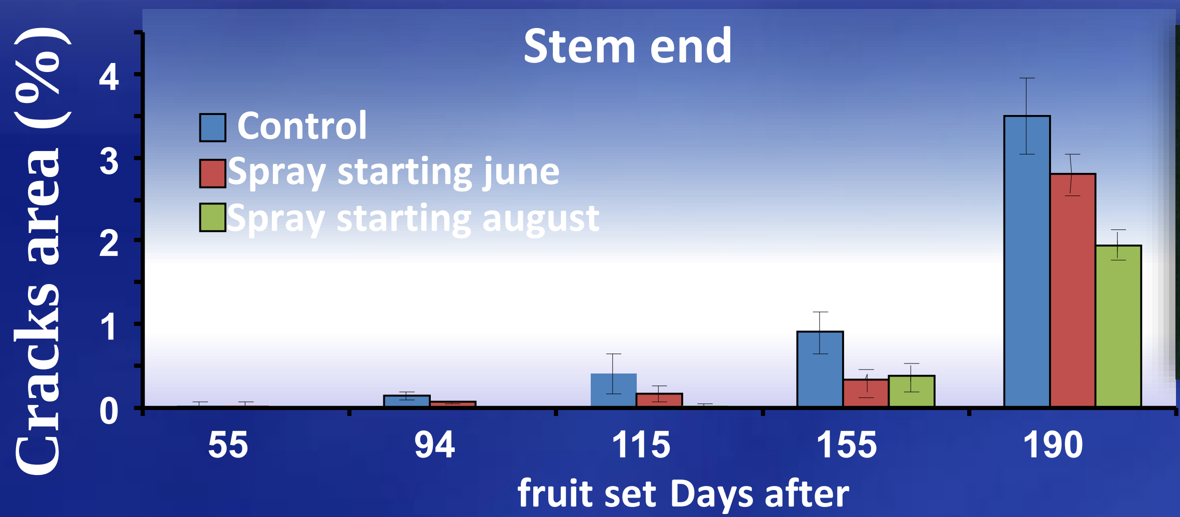
There is a differential susceptibility of tissue under the spals of the fruit

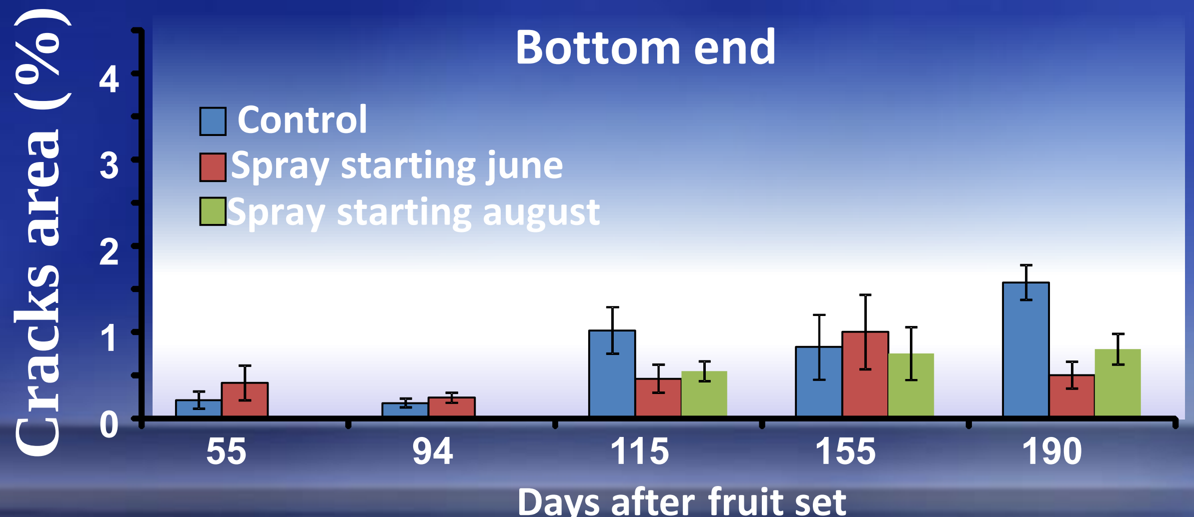
Effect of Superlon treatment on the ethylene evolution during fruit growth

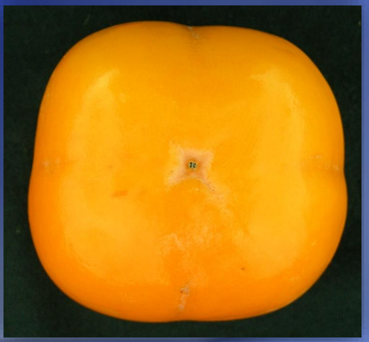


Three monthly Superlon treatments were applied starting from mid June 2012

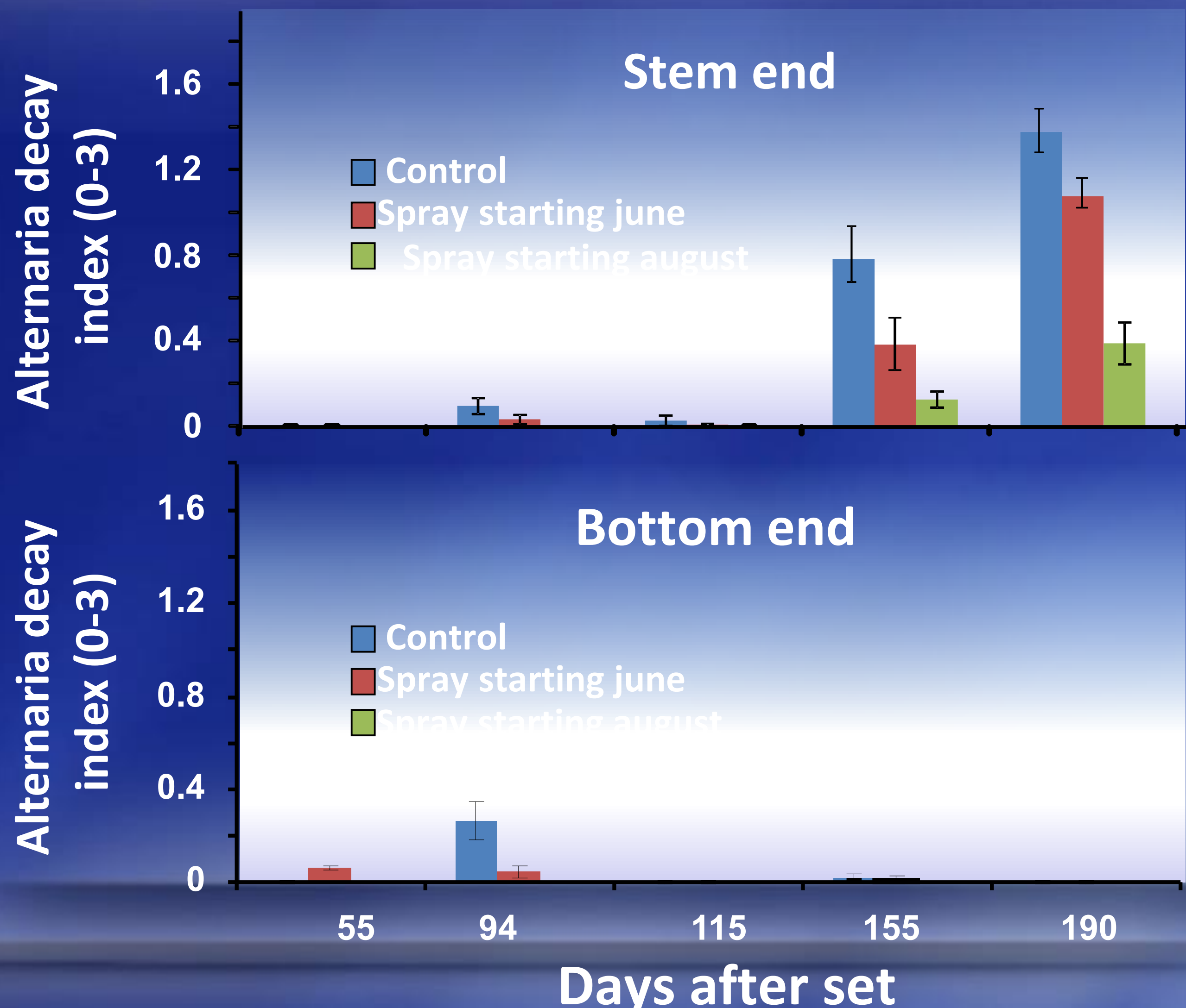
Cracks in the fruit detected by $FeCl_3$ dip treatment

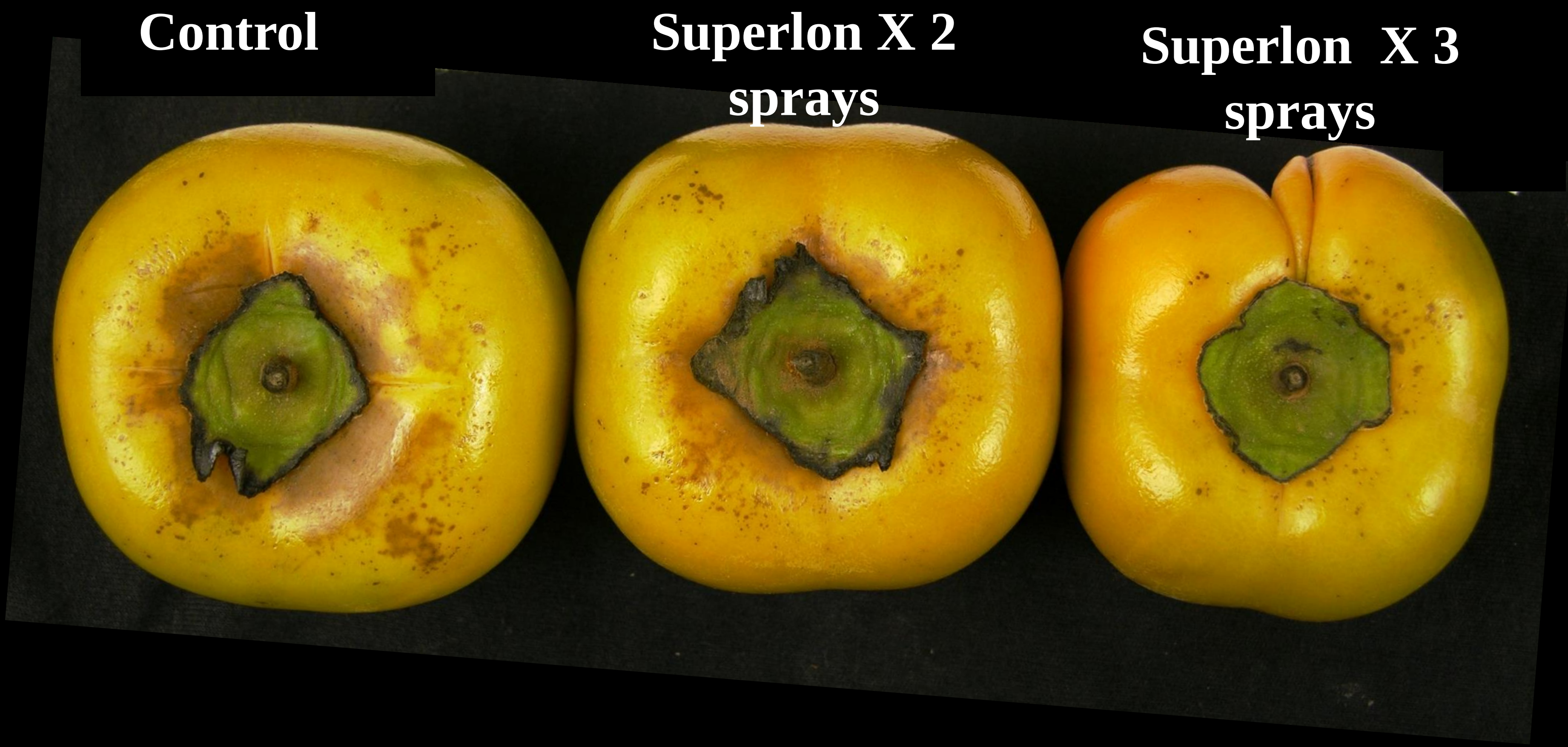






Susceptibility to Alternaria in the fruit treated with Superlon during fruit growth




Control
Superlon X 2 sprays
Superlon X 3 sprays


Control

Superlon


Control
Superlon

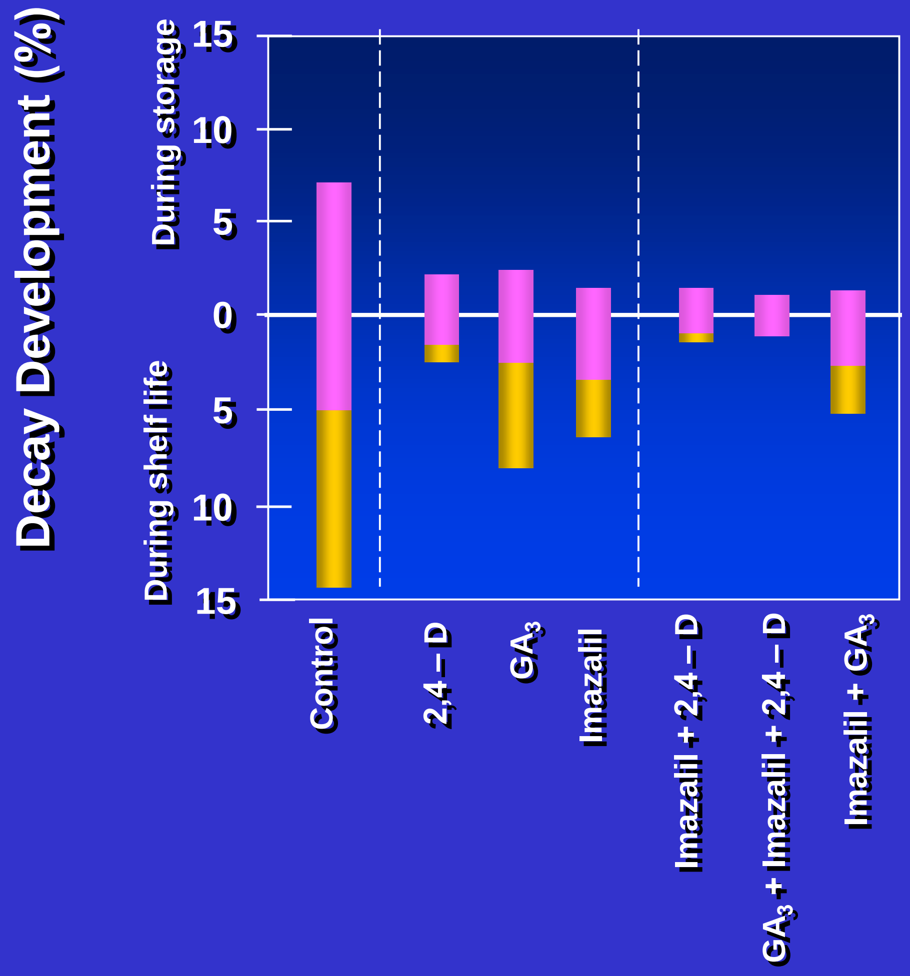
Onion Chives quality

Effect of GA_3 treatment before harvest on the preservation of chives after harvest

Treatments: One day at 1 C+ 1 day at 20 C. This was followed by 6 days at 6 C and the 2 days at 20C

Treatment with GA_3 previous to harvest in combination with plastic bag for MA with high CO_2 and low O_2) delay senescence and decay of cibulet

Postharvest Imazalil and growth regulator on grapefruits citrus fruits



Treatments with growth regulators on navel citrus fruits

GA_3+2,4 D

Control

Effect of growth regulators on stem end development of mango fruits (2,4-D and fungicide prochloraz)

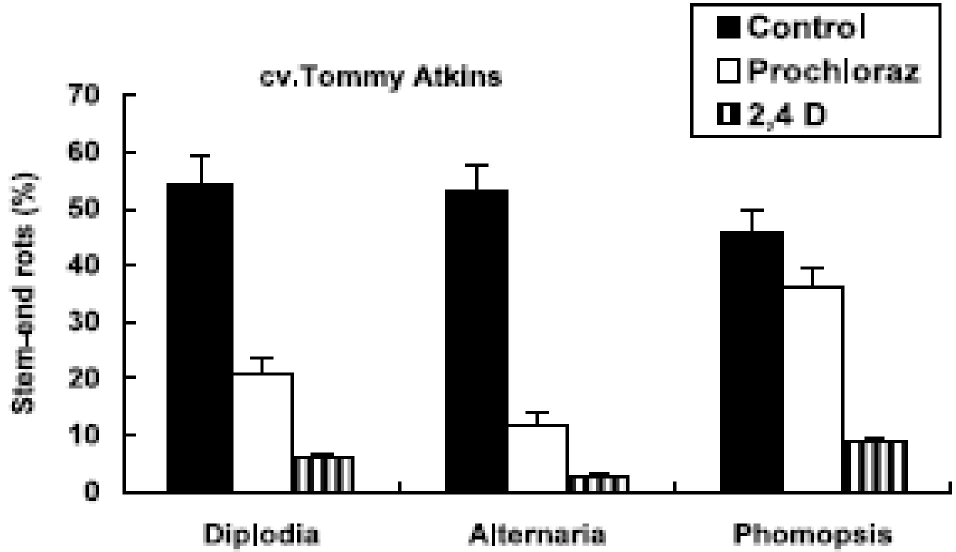


Fig. 2. The effect of 2,4-D and prochloraz dip treatment on the control of the causal agent of stem end rots in fruit of cvs. Tommy Atkins and Keith. Fruit were dipped on the day of harvest in a freshly prepared 75 μg ml^{-1} 2,4-D/wax mixture or 225 μg ml^{-1} prochloraz followed by a wax dip. Fruit were allowed to dry for 30 min and then stored at 14°C for 4 weeks before being transferred to 20°C for ripening. Vertical bars indicate SE of five replications (each of which is ten–12 fruits).

Induce resistance in freshly harvest by inducing fruit metabolism

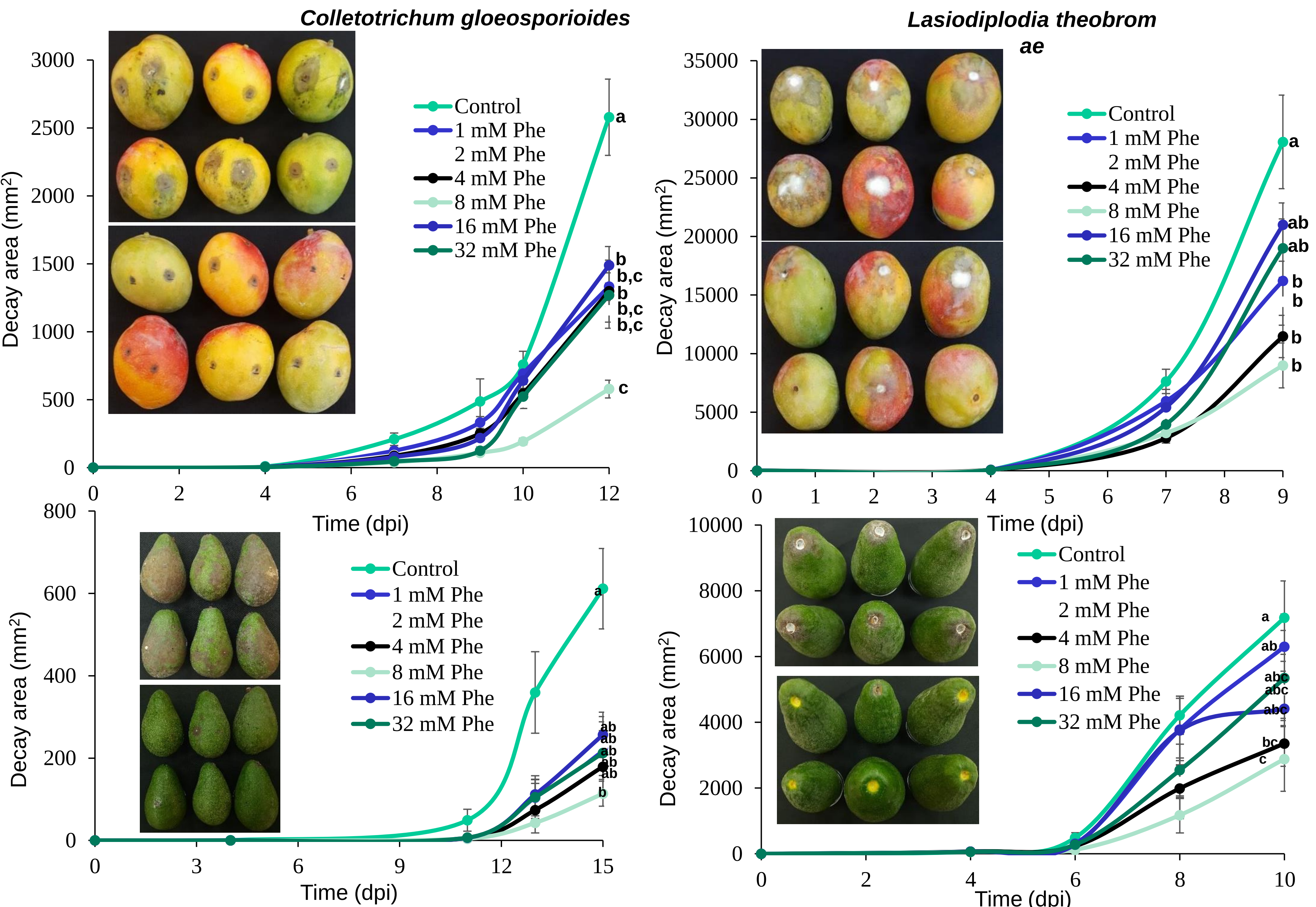
Examples of different genes express or enzyme activities in response application of natural and synthetic chemicals inducing resistance

	Genes and/or enzymes							
Treatment	**SOD**	**CAT**	**POD**	**APX**	**CHT**	**PAL**	**GLU**	**PPO**
Salicylic acid		-	++	-	+	++	+	
Methyl salicylic acid	+	++	++	+				
BTH	+	+	++		+	+	++	
β-aminobutyric ac.			+		+			
Riboflavin			++			+		+
1-MCP	+	+						
Harpin			+++		+++			
Oligandrin			+			+		+
Chitosan			+	++	++	+++	+++	
Yeast saccharide			++		+	+++	+++	
Silicon			+++		+++			
Sodium carbonate			++		-	++	++	

SOD, superoxide dismuatase; CAT, catalase, POD, peroxidase; APX, ascorbate peroxidase;CHT, chitinase; PAL, phenylalanine ammonia lyases; GLU, B-1,3-glucanase; PPO, polyphenol oxidase

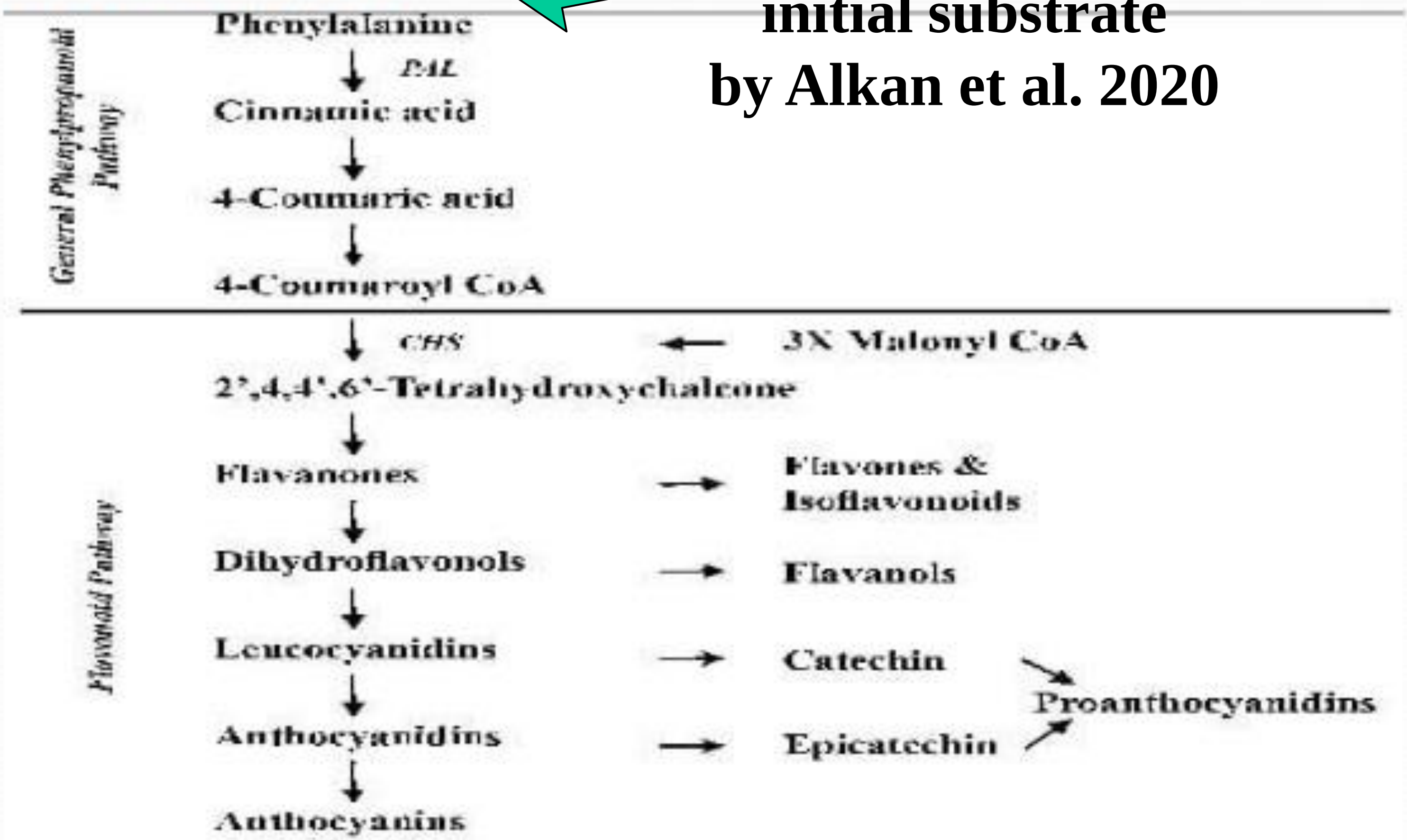
Amino acid inducing resistance

Post harvested induced resistance by phenylalanine



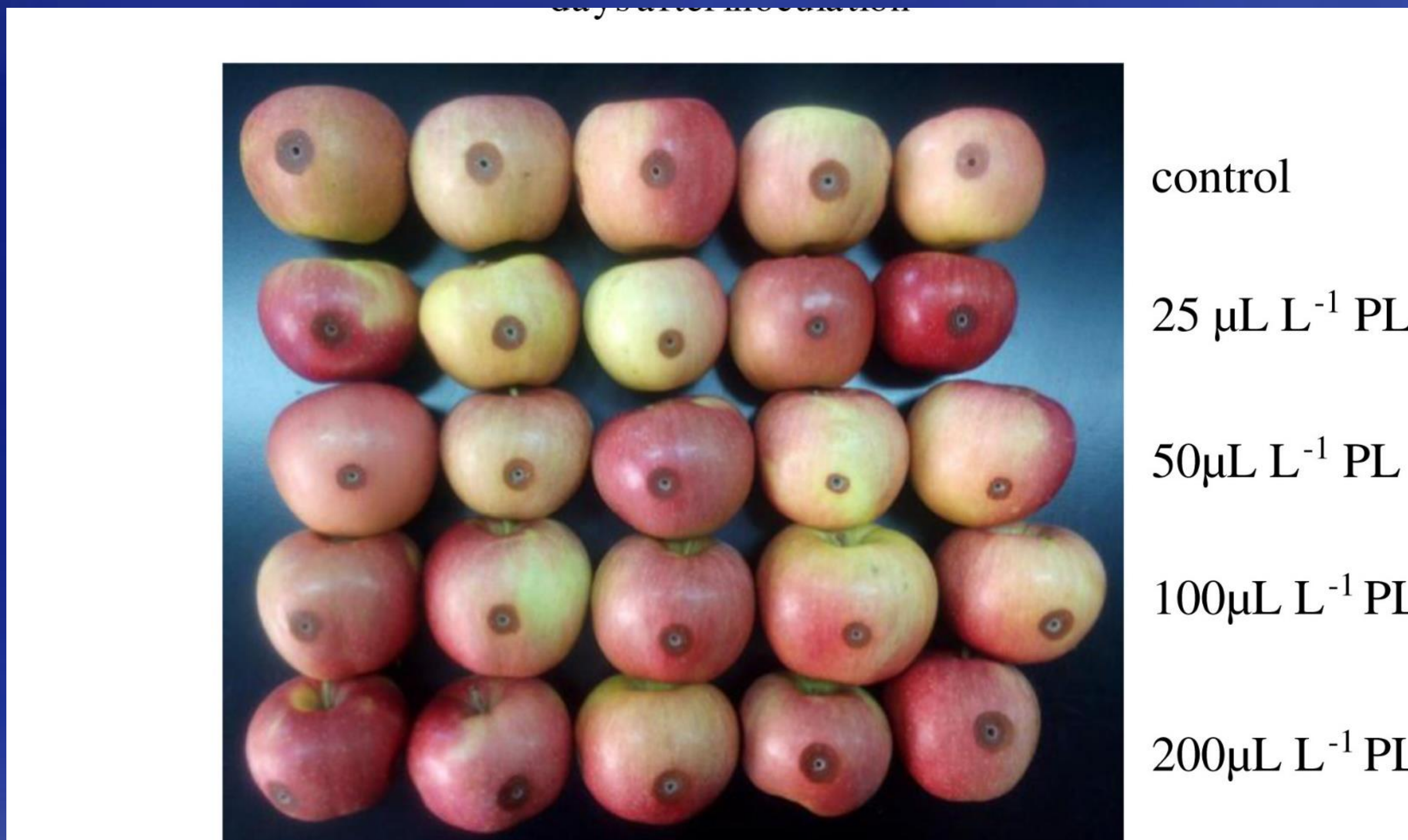
GENERAL PHENYPROPINOID PATHWAY

Addition of the initial substrate by Alkan et al. 2020

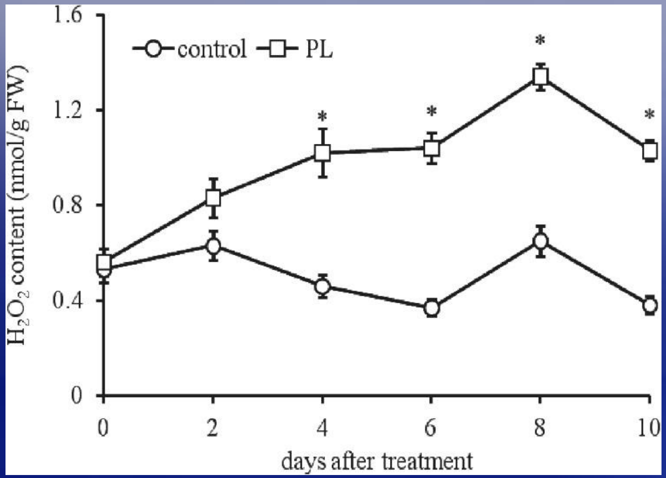


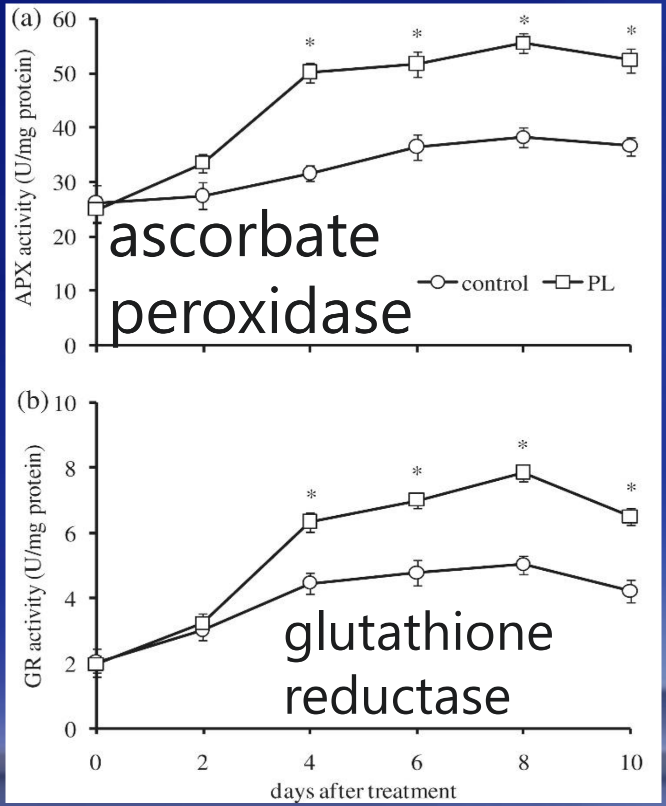
An other amino acid!!!!

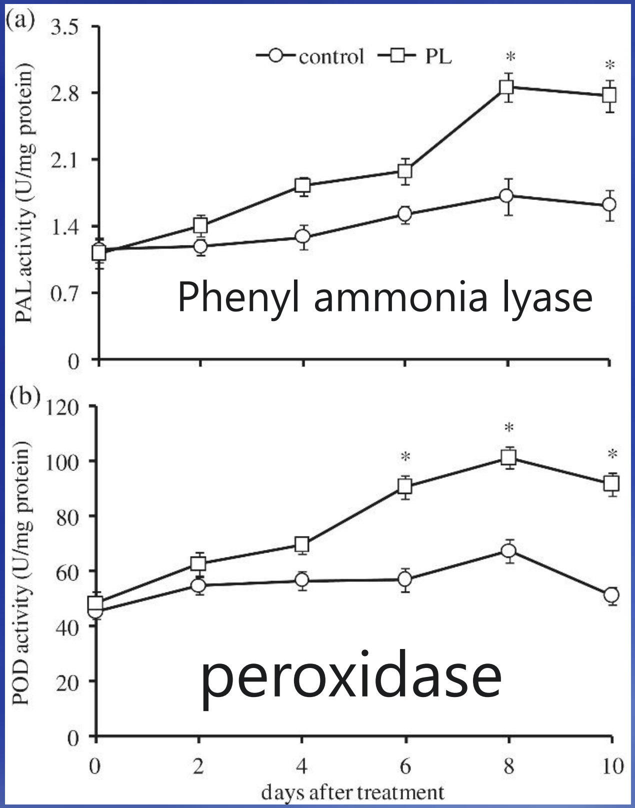
ϵ-poly-L-lysine induce reactive oxygen species metabolism, phenylpropanoid pathway and disease resistance against *Penicillium expansum* in apple fruit



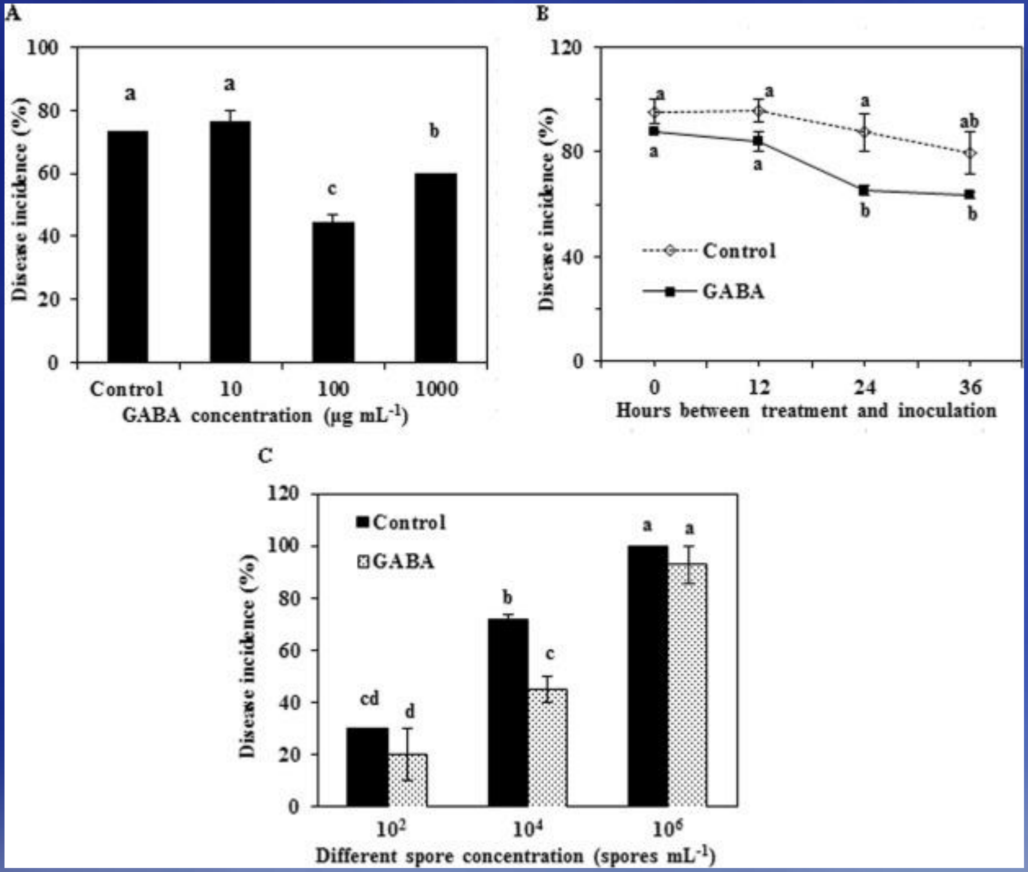
Poly-L-lysine (PL) consists of ϵ-amino and α-hydroxyl that has been used in food preservation

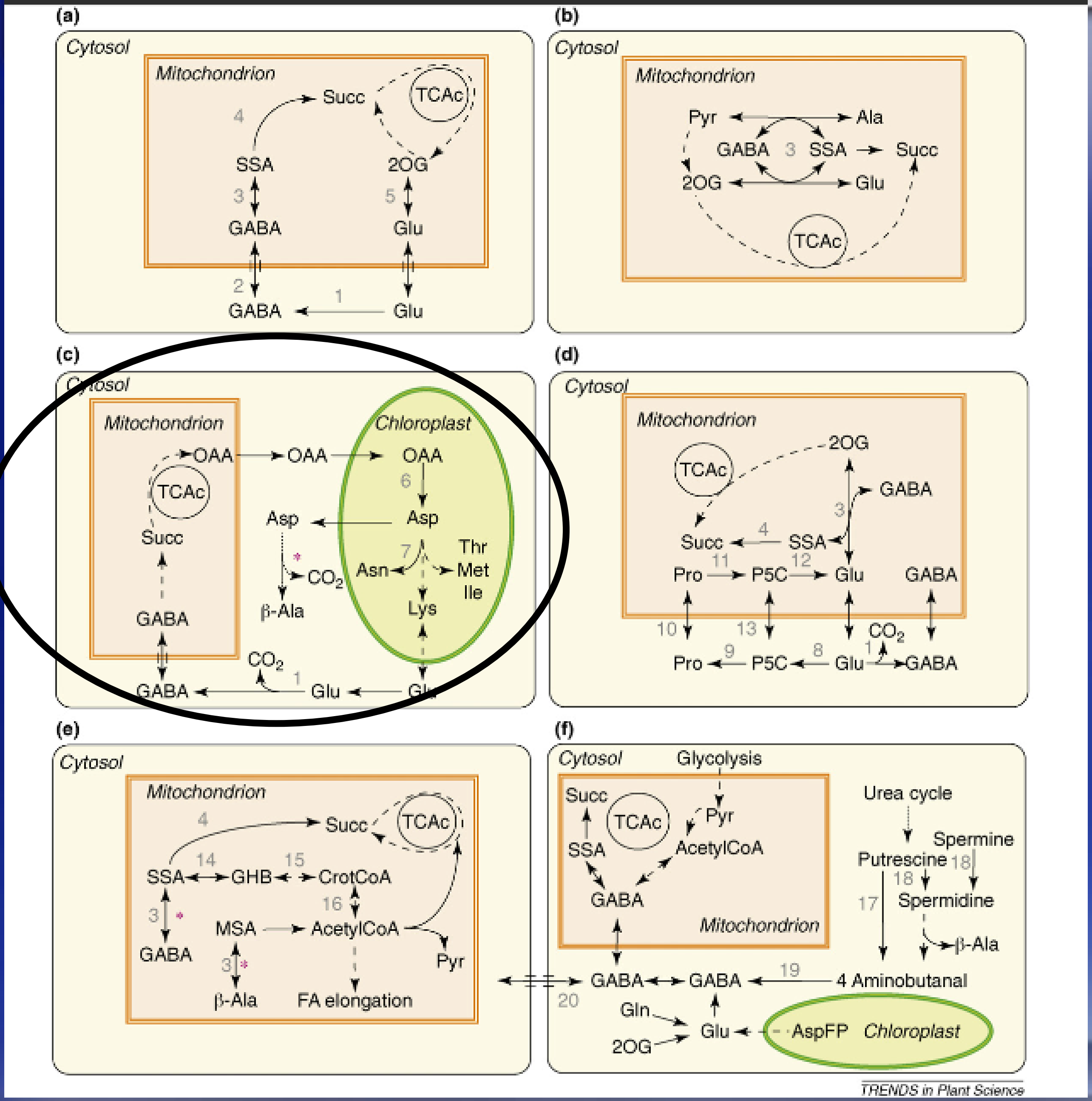






Gamma aminobutyric acid (GABA) is a naturally occurring amino acid that works as a neurotransmitter in our brain. Neurotransmitters function as chemical messengers and were used as inducer of **tomato resistance against Alternaria**



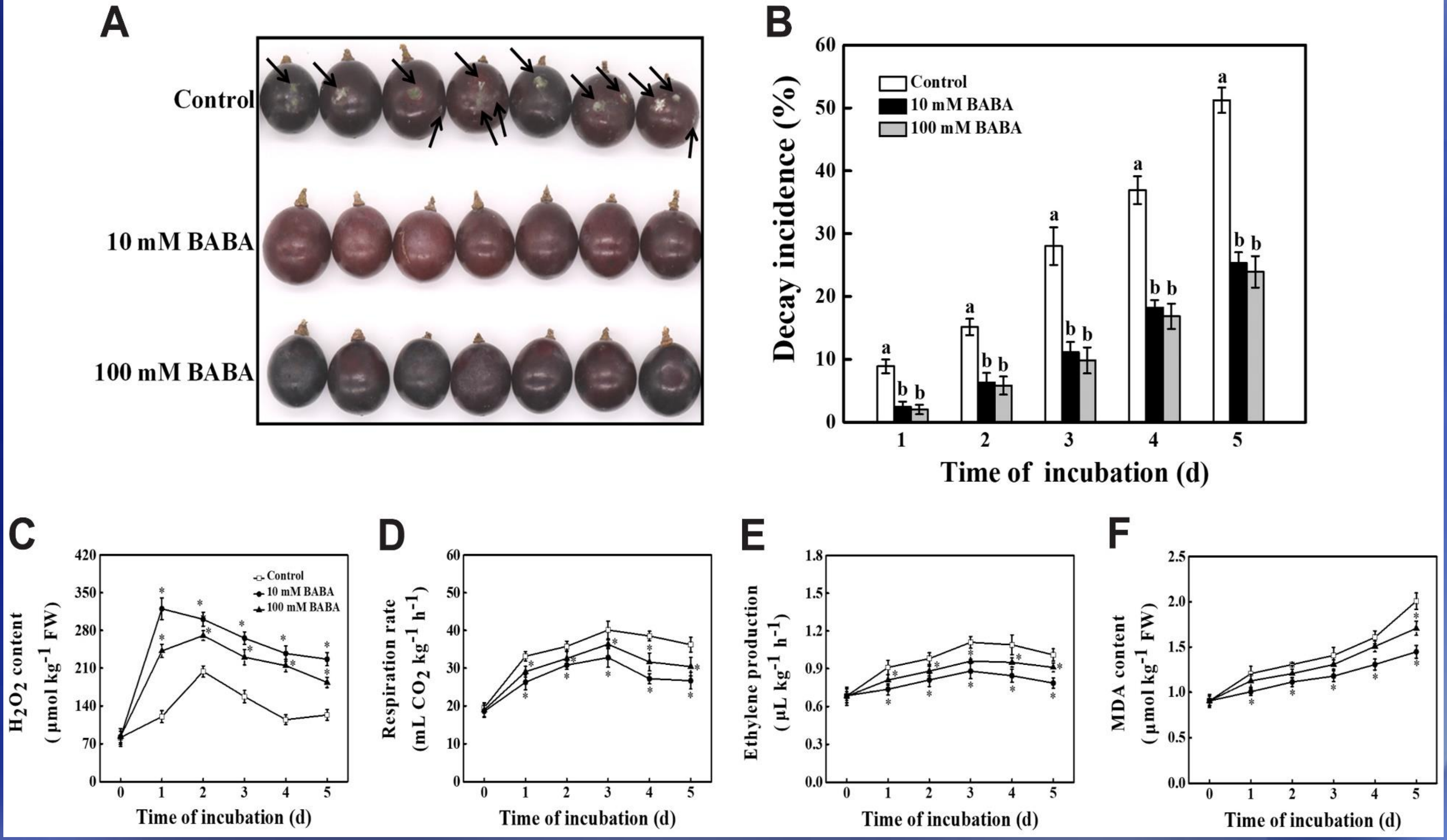


GABA is associated with GABA shunt, a pathway with roles in signalling, pH regulation, redox regulation, energy production and maintenance of carbon/nitrogen (C/N) balance, linking amino acid metabolism and the tricarboxylic acid (TCA) cycle ([Fait, Fromm, Walter, Galili, & Fernie, 2008])

The activation of metabolic pathways by GABA may function as anti-cell death defence strategy against necrotrophic pathogens in invaded cells. Taken together, it could be hypothesized that activation of the GABA shunt might be strongly associated with resistance mechanism.

β-aminobutyric acid (BABA)

A, Changes in disease phenotype of Botrytis, B, decay incidence, C, H2O2 content, D, respiration rate, E, ethylene production and F, malondialdehyde (MDA) content in grapes under β-aminobutyric acid (BABA) treatments at 0, 10, and 100 mM during incubation at 20°C for 5 days.



Published in: Chunhong Li; Kaituo Wang; Changyi Lei; Shifeng Cao; Yixiao Huang; Nana Ji; Feng Xu; Yonghua Zheng; *MPMI* 2021, 34, 1250-1266.
 • DOI: 10.1094/MPMI-06-21-0142-R

β-aminobutyric acid (BABA)

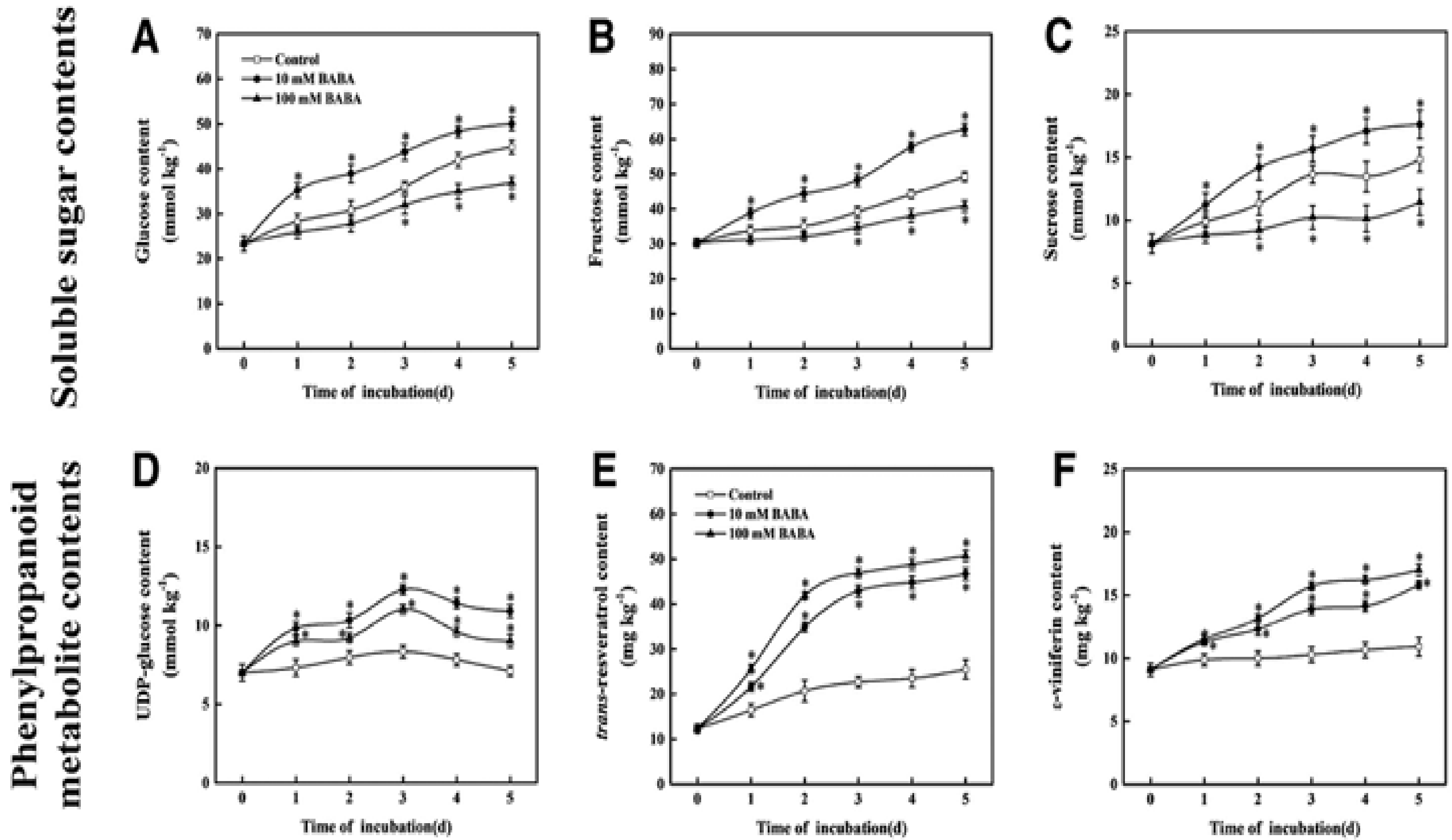
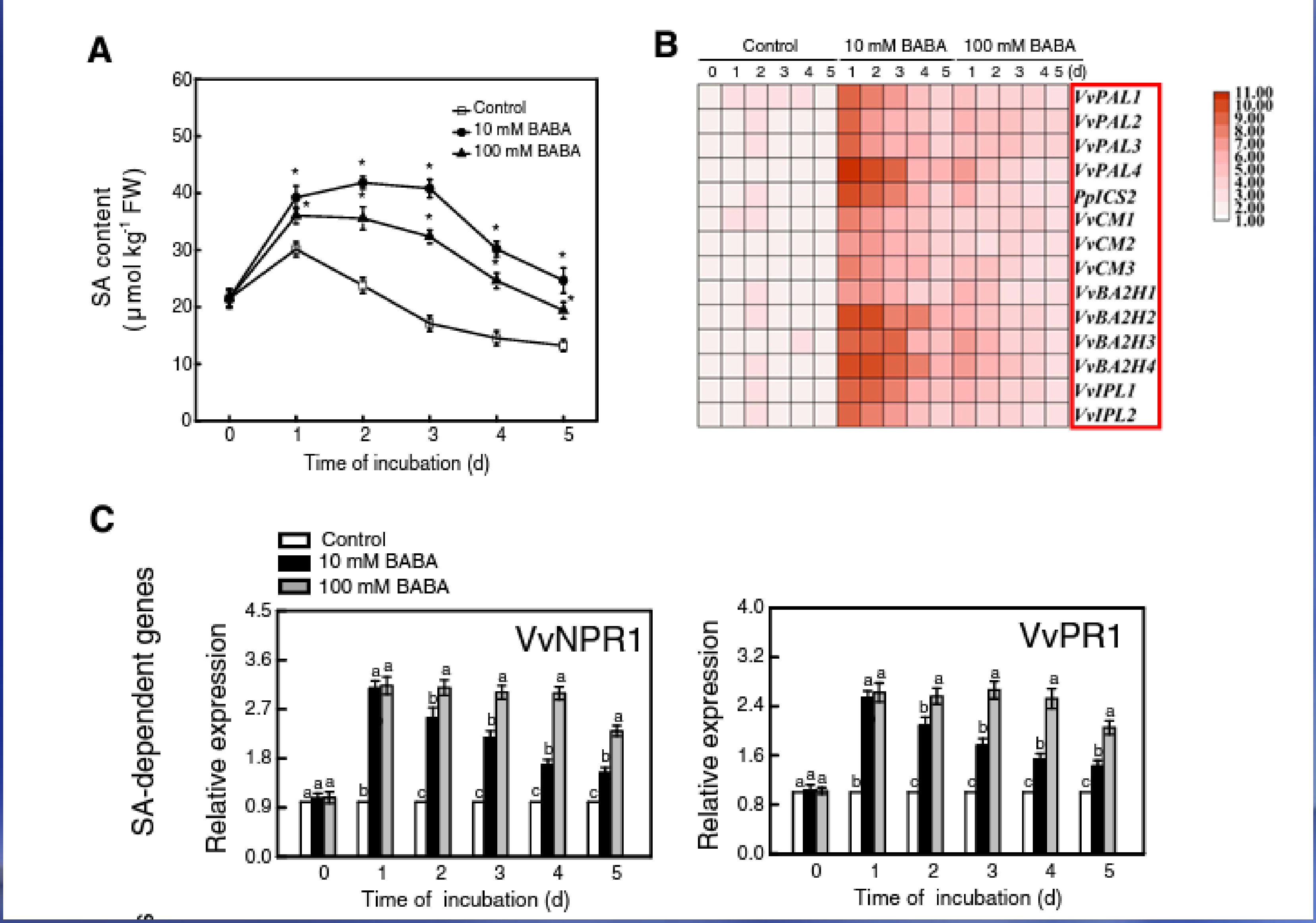


Fig. 2. β-Aminobutyric acid (BABA) treatments affected the contents of soluble sugars, including **A,** glucose, **B,** fructose and **C,** sucrose, and of phenylpropanoid metabolites, including **D,** UDP-glucose, **E,** *trans*-resveratrol, and **F,** ε-viniferin, in grape berries. Data are recorded as the mean ± standard error (SE) of triplicate assays. Statistical vertical bars represent SE. An asterisk (*) indicates significant differences between BABA-treated and untreated berries ($P = 0.05$).

A, b-Aminobutyric acid (BABA) **treatments affected the salicylic acid (SA)** content and B, the **expression levels of SA biosynthesis genes** and C, pathogenesis-related (PR) genes (VvNPR1, VvPR1, VvGNS, VvCHI, VvPDF1.2,andVvHel) **in grape berries**.



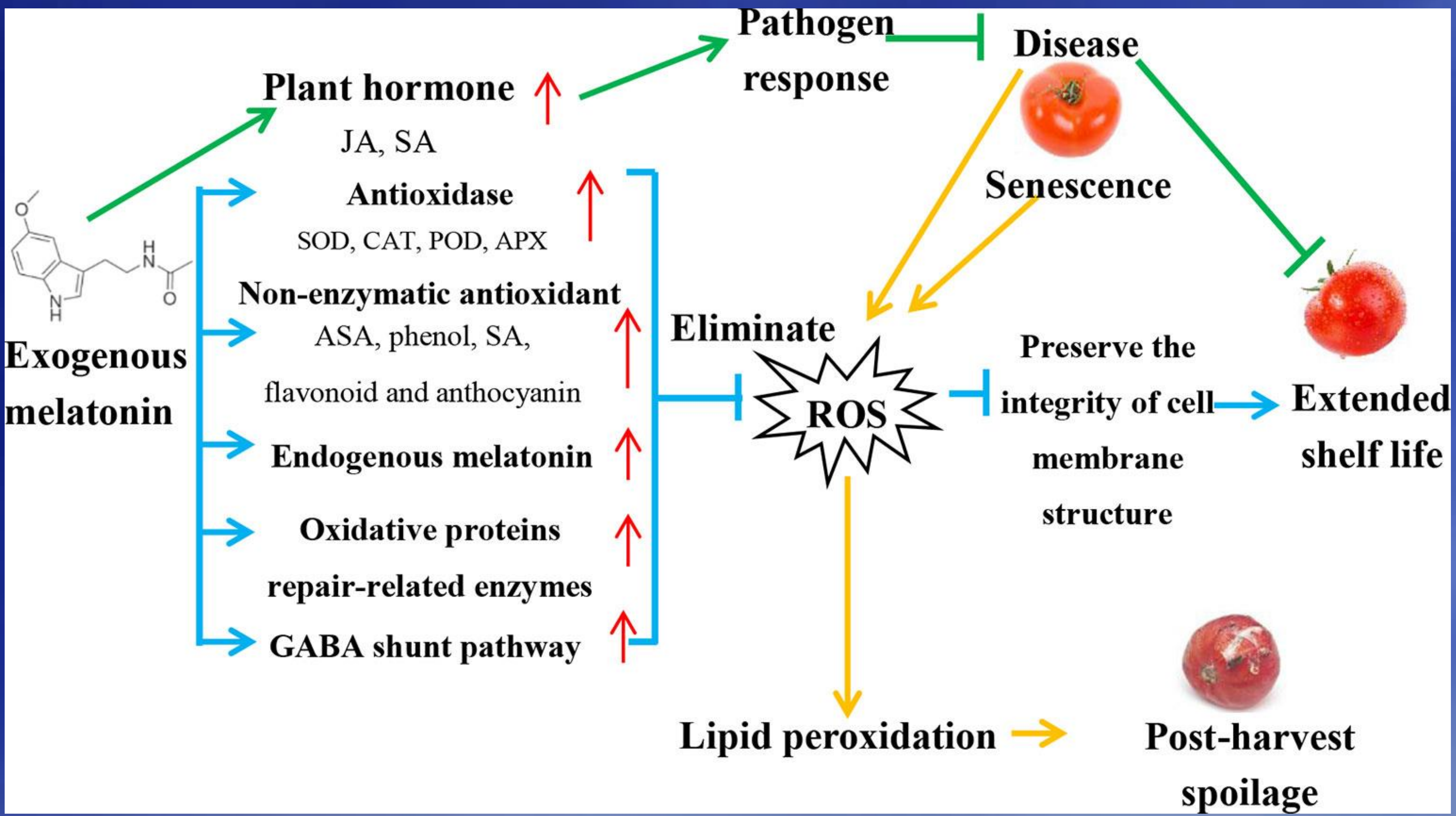
Melatonin

Melatonin is a ubiquitous molecule and plays an important role in 1. animals, 2. humans and 3. plants, such as delaying senescence, exerting antioxidant effects, regulating growth and development, and facilitating plant adaption to stress conditions.

Endogenous melatonin plays prominent roles in the ripening and post-harvest process of fruits and vegetables.

Exogenous application of melatonin removes excess reactive oxygen species from post-harvest fruits and vegetables by increasing antioxidant enzymes, non-enzymatic antioxidants, and enzymes related to oxidized protein repair.

Melatonin



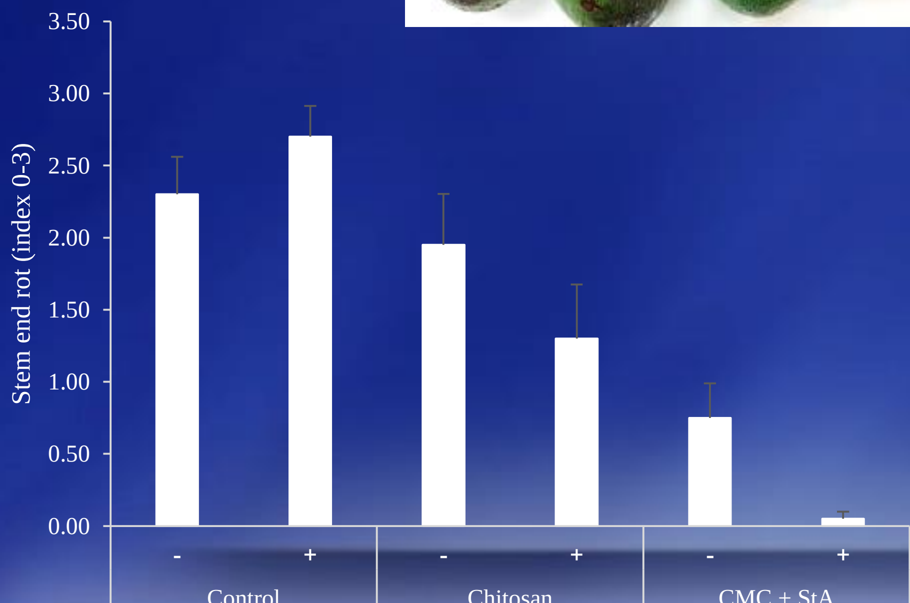
Pathogen response
Disease
Plant hormone
JA, SA
Antioxidase
SOD, CAT, POD, APX
Non-enzymatic antioxidant
ASA, phenol, SA,
flavonoid and anthocyanin
Endogenous melatonin
Oxidative proteins
repair-related enzymes
GABA shunt pathway
Exogenous melatonin
Senescence
Eliminate
ROS
Preserve the integrity of cell membrane structure
Extended shelf life
Lipid peroxidation
Post-harvest spoilage

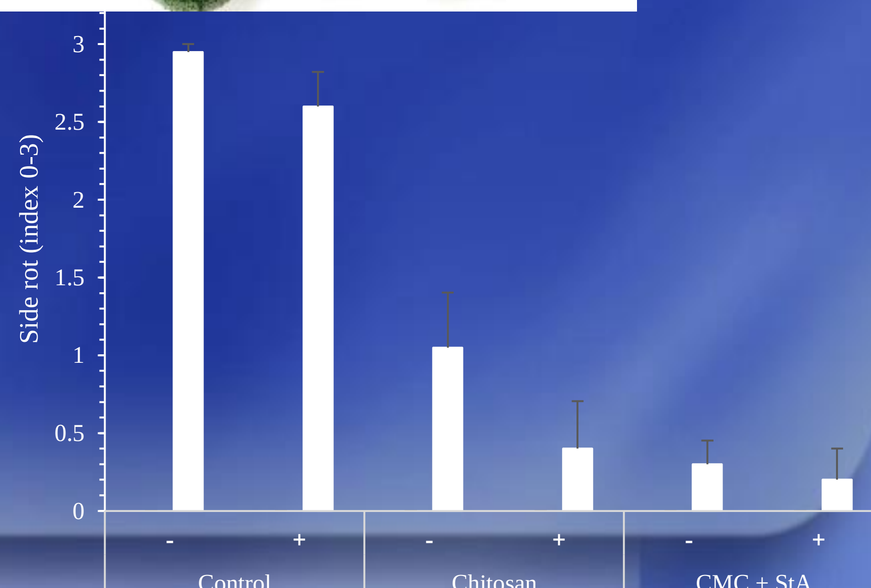
Chitosan and coating in Avocado fruit

Control **Phenylalanine**

Control

Chitosan





Methyl jasmonate (MeJA).

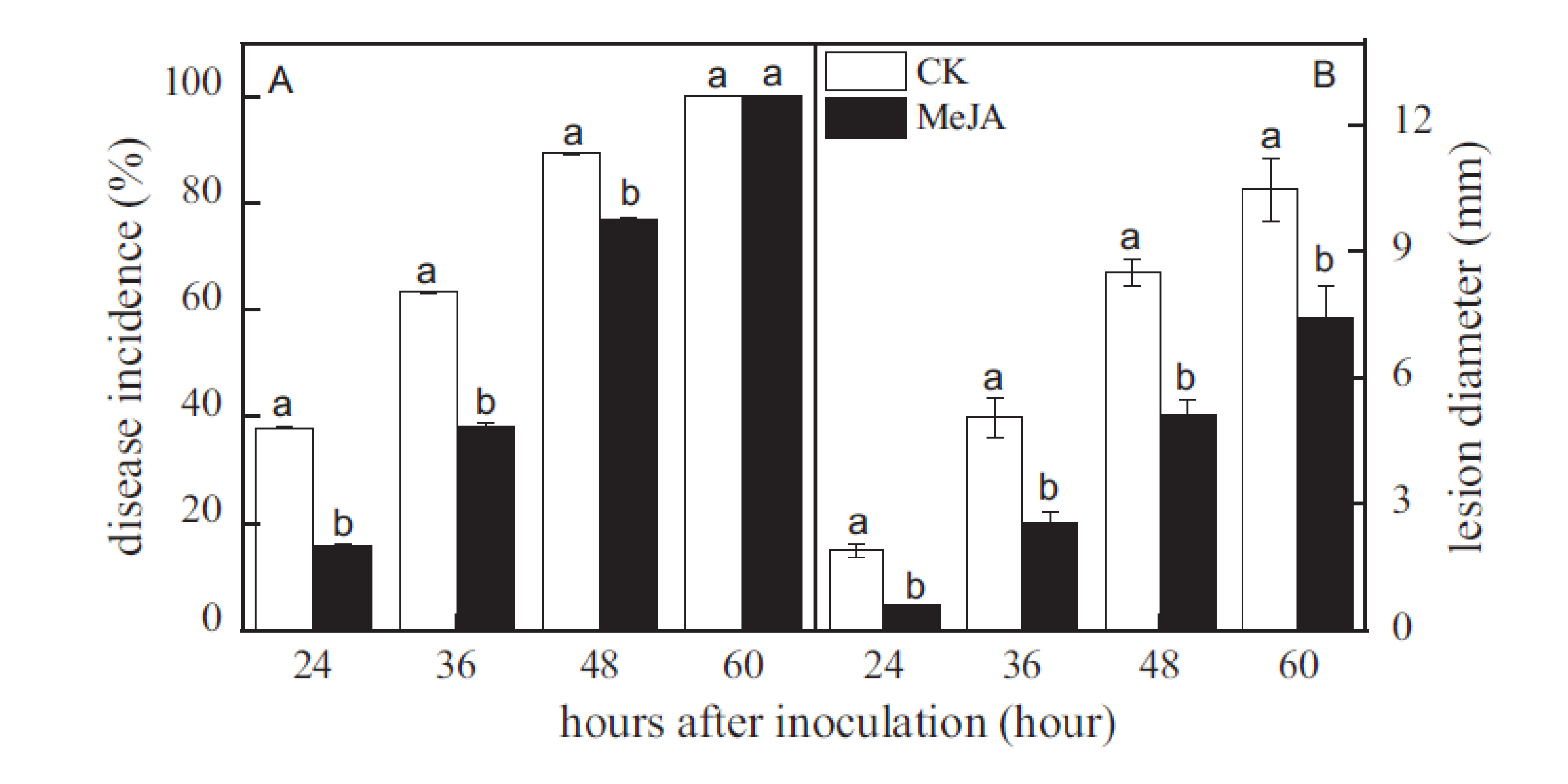
JA plays a prominent role in plant defense response.

In tomato exogenous MeJA treatment inhibited *B. cinerea decay*, by inducing H_2O_2 accumulation and antioxidative activity

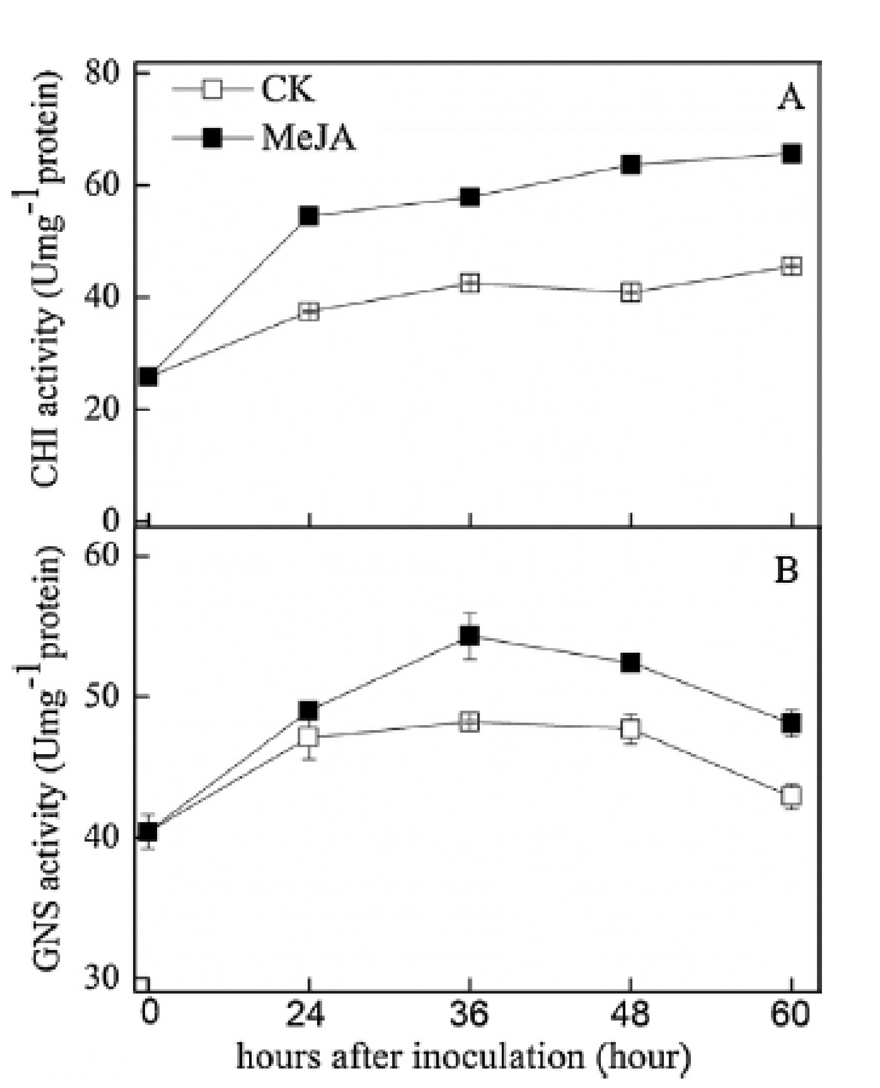
In peach exogenous MeJA treatment increases the activities of chitinase, β-1,3-glucanase, and POD in peach fruit, and induces resistance against *Monilinia fructicola* and *P. expansum*

MeJA-treated fruits show an H_2O_2 burst and the accumulation of phenolic compounds, such as lignin and phytoalexin, which is beneficial for fruit defense responses.

MeJA-induced resistance in harvested grapes inoculated by Botrytis



MeJA-induced the activation of pathogenesis-related proteins such as CHI (chitinases) and GNS (B-1,3-glucanases) in grapes inoculated by Botrytis



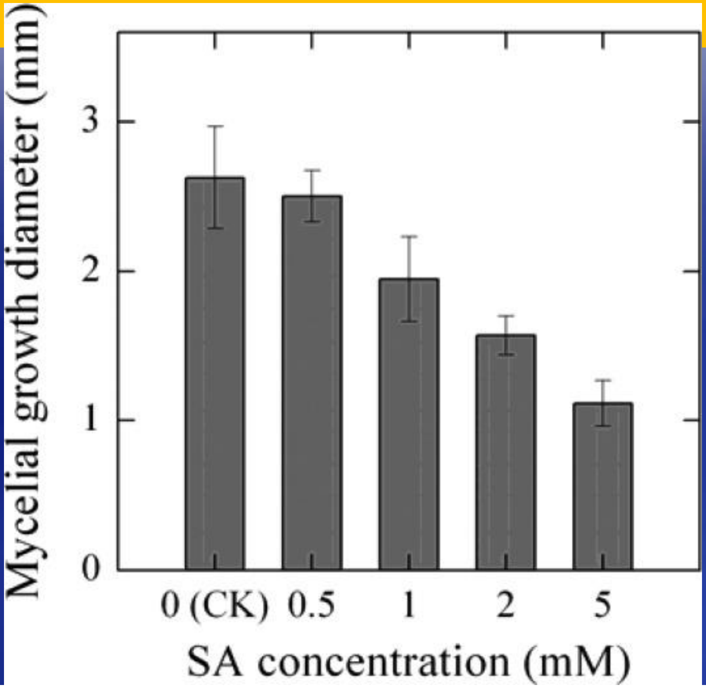
Methyl Salicylate

SA improved the resistance to *Alternaria alternata* and *P. expansum* by inducing the activity of anti-oxidant enzymes and pathogenesis-related proteins in sweet chery.

In citrus fruit SA reduced disease severity by inducing the accumulation of H_2O_2, primary metabolites, and lipophilic polymethoxylated flavones (phenols)

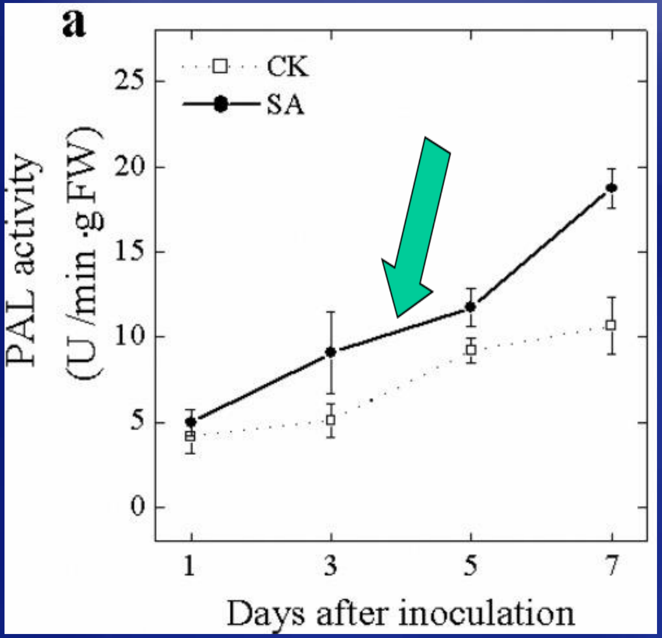
SA may also facilitate H_2O_2 accumulation during the oxidative burst induced by infection with virulent pathogens

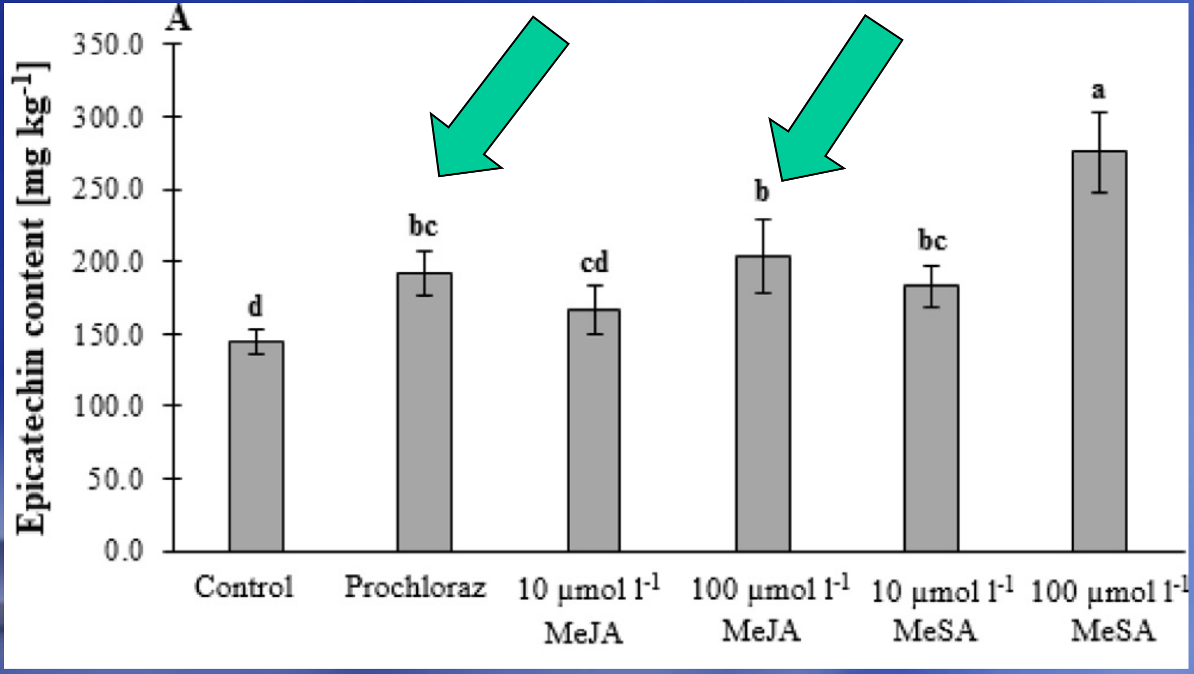
Effect of SA



0 0.5 1 2 5 mM

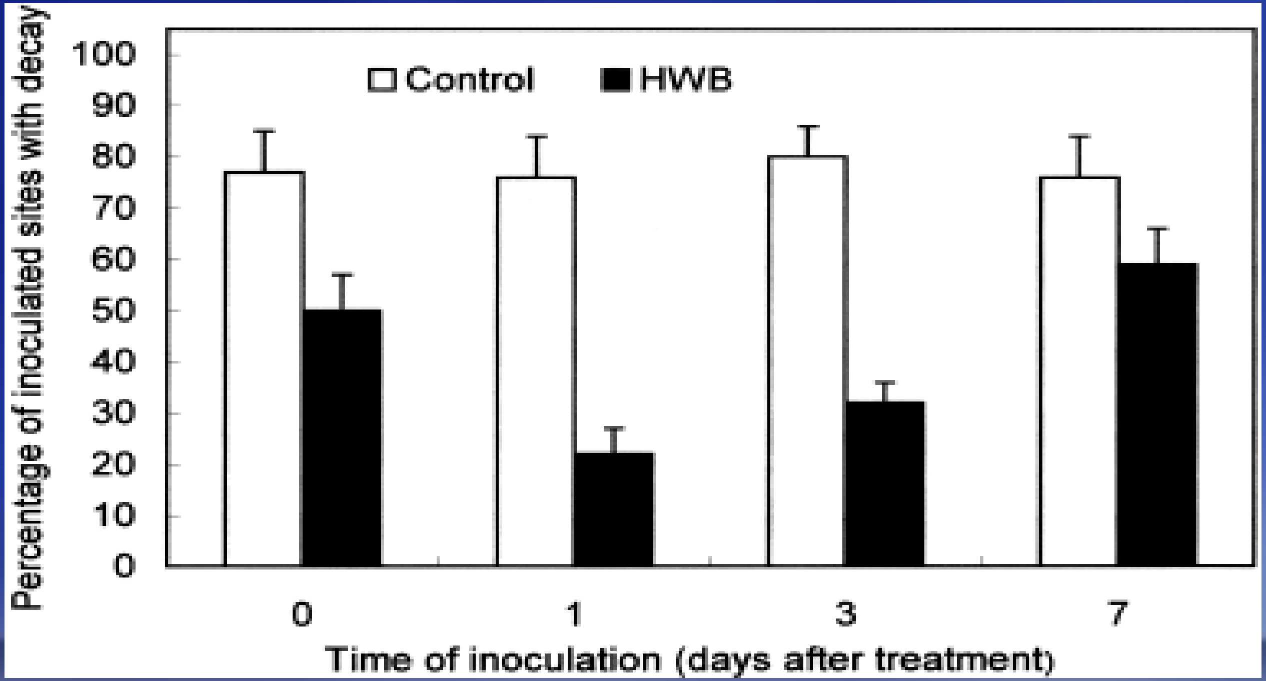
PAL activity and epicatechin content in the skin of naturally infected ‘Hass’ avocado fruit (2 C for 14 d +6–7 d shelf-life at 20 C)



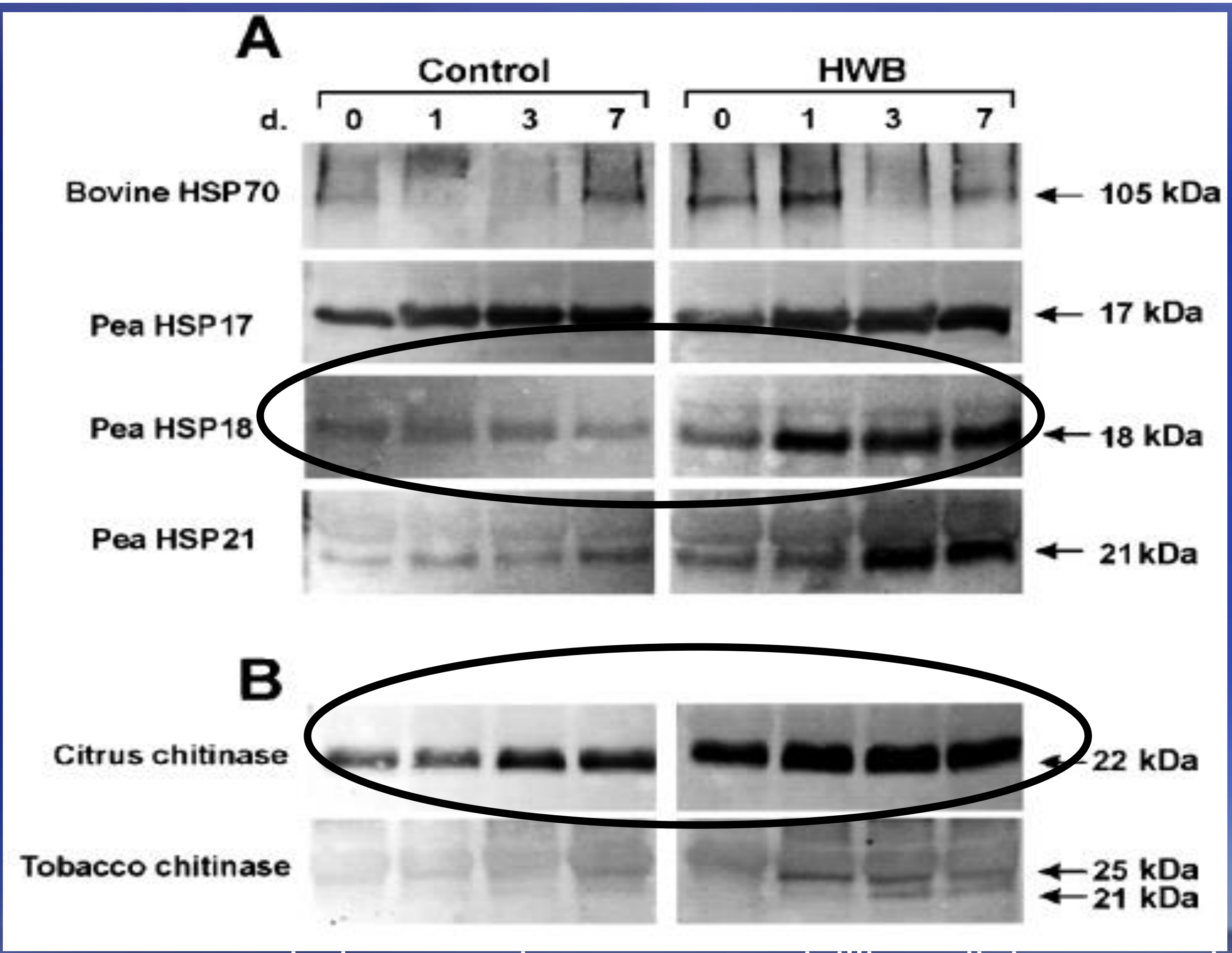


Heat treatments inducing resisitance

A hot water treatment induces resistance to *Penicillium digitatum* and promotes the accumulation of heat shock and pathogenesis-related proteins in grapefruit flavedo

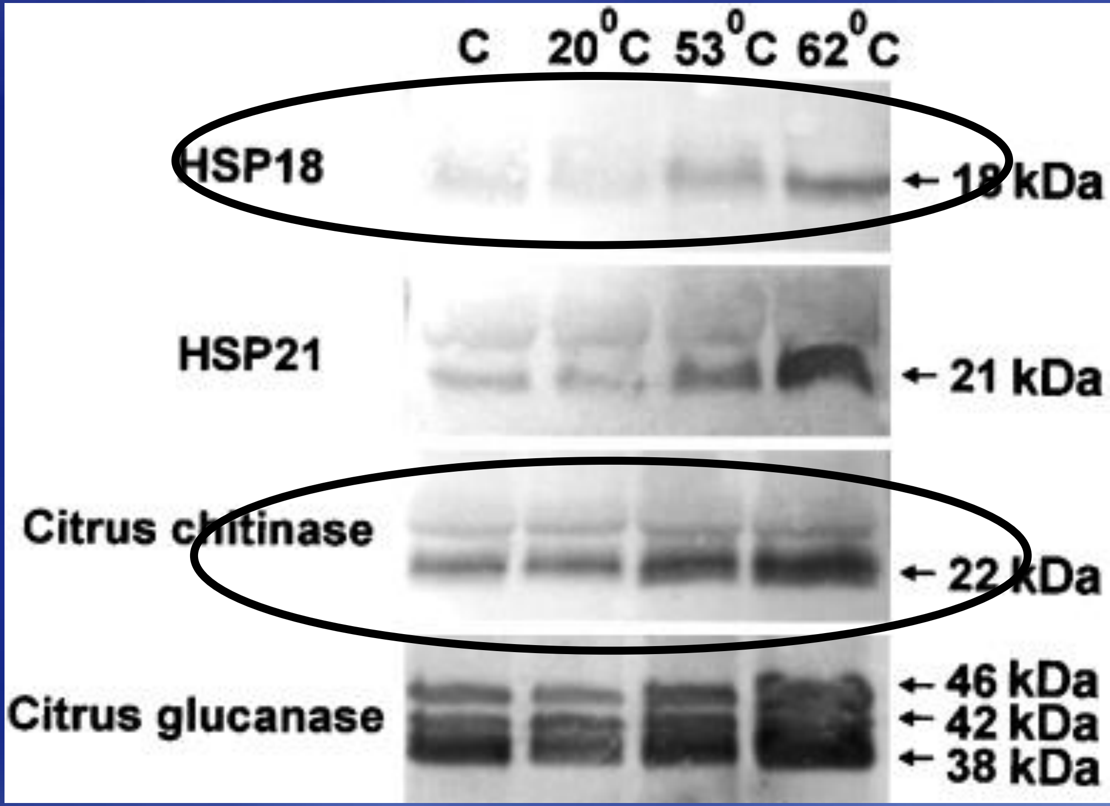


Effects of a postharvest HWB treatment on the accumulation of heat-shock (A), chitinase (B) in 'Star Ruby' grapefruit peel tissue.



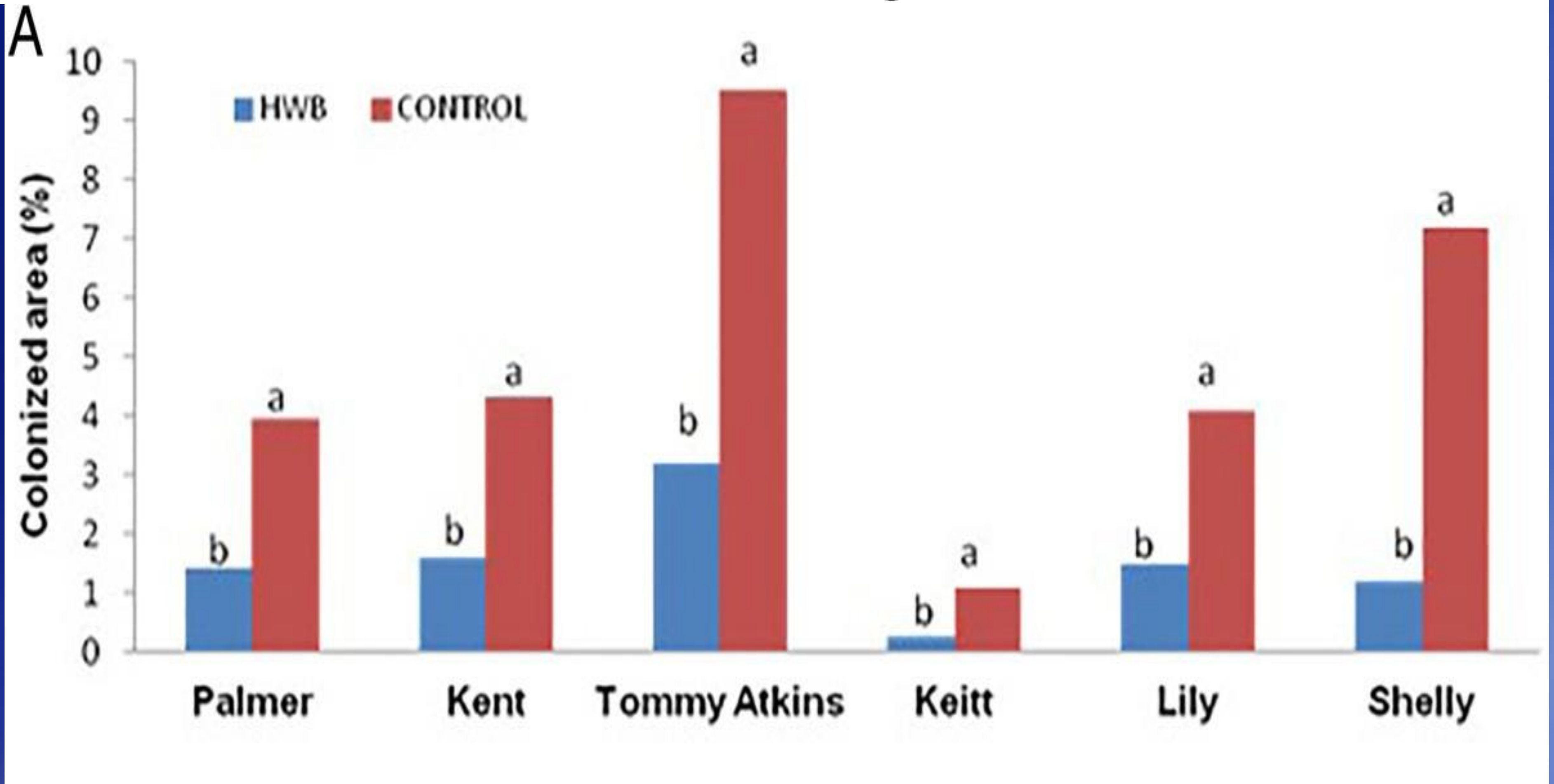
A hot water treatment induces resistance to Penicillium digitatum and promotes the accumulation of heat shock and pathogenesis-related proteins in grapefruit flavedo

A hot water treatment induces resistance to *Penicillium digitatum* and promotes the accumulation of heat shock and pathogenesis-related proteins in grapefruit flavedo

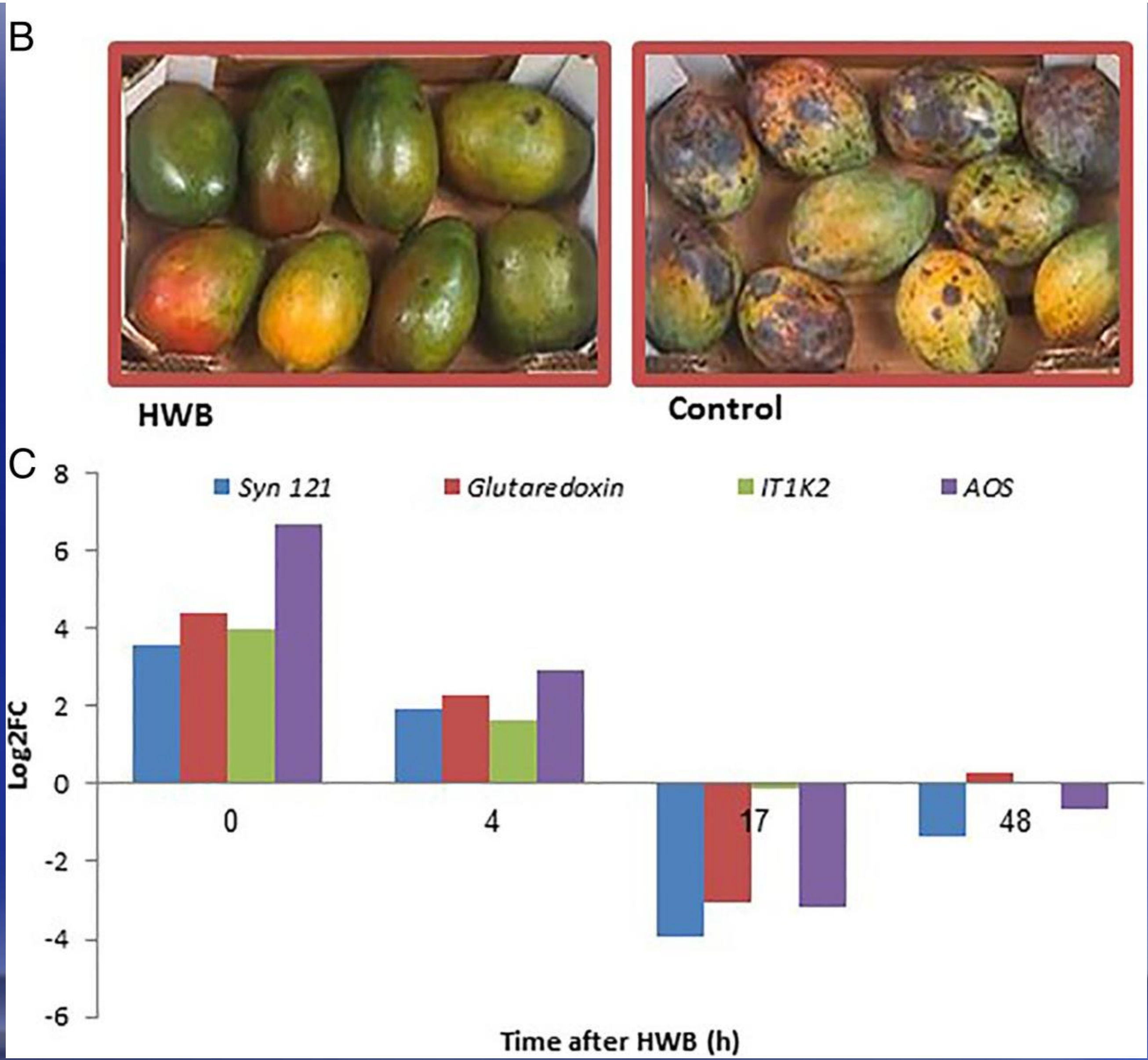


Physiologia Plantarum, Volume: 111, Issue: 1, Pages: 17-22, First published: 07 July 2008, DOI: (10.1034/j.1399-3054.2001.1110103.x)

Induce resistance of mango fruits to Alternata attack by the host water brushing



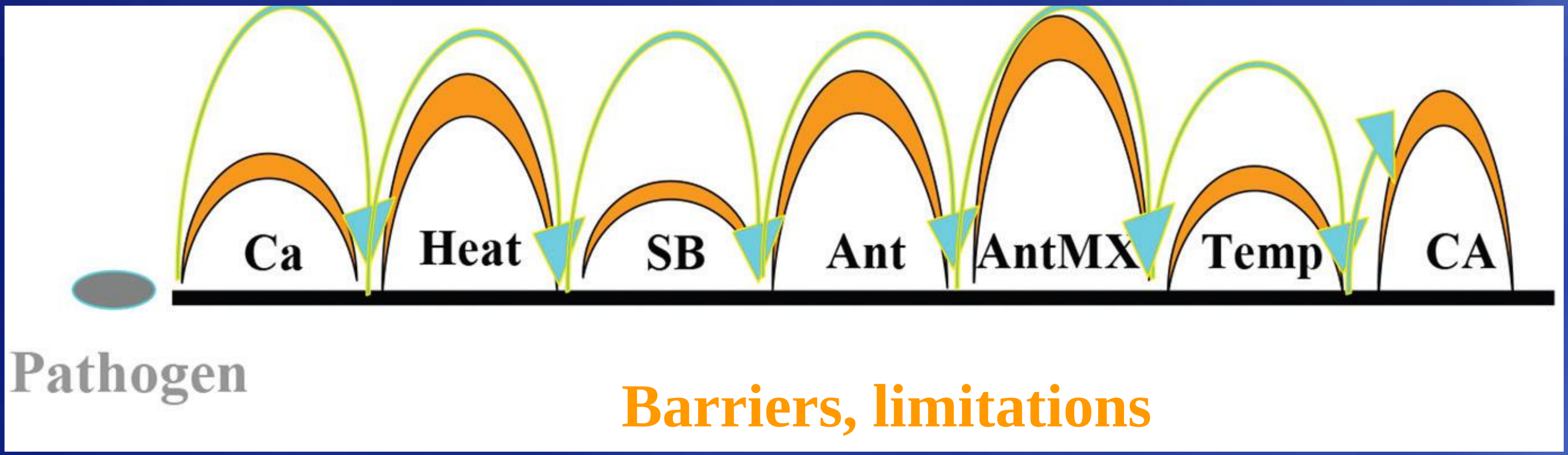
Differential gene expression following the HWB treatment during storage at different periods after the HWB treatment



Induce resistance can צצצוS be obtained by

- External precursors
- Fungal stress induction of fruit metabolism
- Use of external applied plant products (Chitosan, silicon)
- Stress treatments like heat
- All these treatment inhibit decay development but are not enough for disase control for long strage conditions

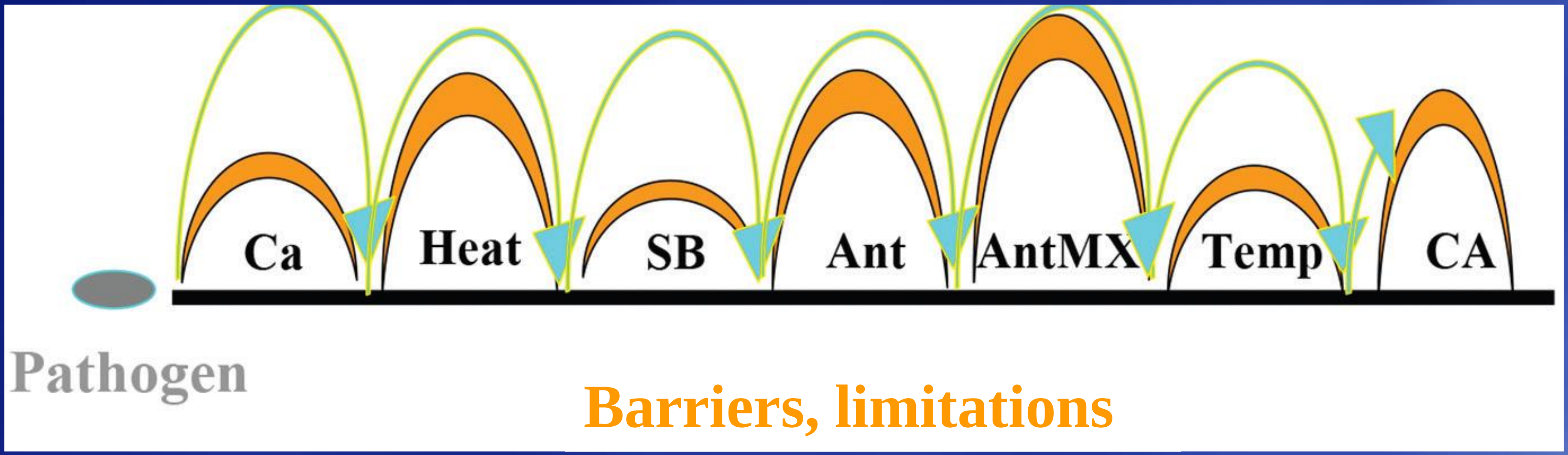
Multi-barrier concept for managing postharvest diseases



Each treatment in an integrated program is considered a barrier (marked in orange) for the pathogen that has the potential to reduce/inhibit decay incidence/severity to varying degrees (height of barrier).

Take home message

Multi-barrier concept for managing postharvest diseases



Ca = calcium, Heat = 38°C for 4 d, SB = sodium bicarbonate, Ant = antagonist, AntMX = antagonist mixture, Temp = low storage temperature, CA = controlled atmosphere storage

Principles of Plant Disease Management
Summary of last lesson

- **Preventive**

  - Cultural practices: avoidance of the pathogen (cultural practices)
  - Eradication of the pathogen in the orchard and in the store room
  - Induce resistance (Hormonal, Chemical or biological).

- **Protection/Erradication by chemical control (use of fungicides)**