Calcium Use in Apples: An Update

M. Elena Garcia, PhD

The University of Vermont

uvmEXT University of Vermont Extension

Physiological role of calcium

- Calcium is perhaps the most important mineral determining the quality of fruit, particularly in apples and pears because these fruits are stored for long periods of time (Faust, 1989).

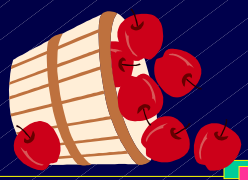
Physiological role of calcium

- Fruits with low Ca concentration
  - More susceptible physiological disorders
    - Bitter pit
    - Cork spot

M. E. Garcia
UVM Apple Team

Physiological role of calcium

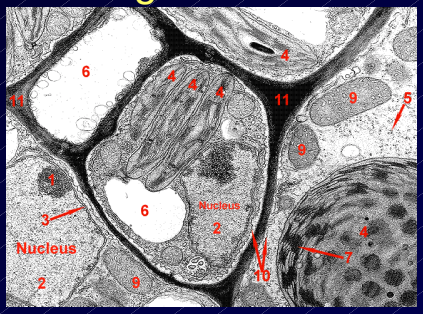
- Low Ca fruit
  - Hasten fruit senescence
  - Increased rate of softening of fruit
  - Regulation of respiration
  - Ethylene production inversely related to Ca concentration



M. E. Garcia
UVM Apple Team

Physiological role of calcium

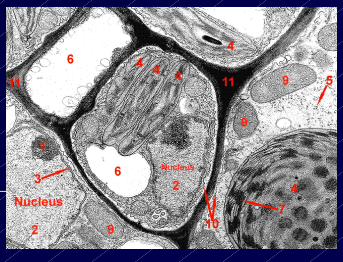
- At the cellular level, Ca plays a binding role in the complex polysaccharides and proteins forming the cell wall



M. E. Garcia
UVM Apple Team

Physiological role of calcium

- In the outer cell membrane, lower Ca concentrations causes leakiness of the the membrane
- Modulates the transfer of extracellular signals into intracellular space



M. E. Garcia
UVM Apple Team

Physiological role of calcium

- The tissue Ca concentration at which these desirable effects is usually higher than concentrations that the fruit normally accumulates

M. E. Garcia
UVM Apple Team

Ca Levels

- Fruit Ca levels vary from year to year
- Between orchards
- Between fruit on the same branch
- Within the apple fruit

M. E. Garcia
UVM Apple Team

Ca levels in fruit

M. E. Garcia
UVM Apple Team

Ca uptake from soil

- Ca can be absorbed only by the young root tips that are not suberized. This area is behind the root tip

M. E. Garcia
UVM Apple Team

Ca uptake

- Ca moves from the soil into plant in a passive manner
- Within the plant it moves with the transpiration stream
  - Intensity of transpiration controls upward movement of Ca

M. E. Garcia
UVM Apple Team

Ca uptake from foliar sprays

- Ca sprayed on leaves and fruits enters into the tissue mostly though openings such as the stomata and lenticels
  - There is very little movement of the Ca once it is inside.

M. E. Garcia
UVM Apple Team

Factors affecting Ca absorption

- Sites of entry
- Concentration of soluble Ca in solution
- Time in solution
- Relative humidity
- Additives to solution

M. E. Garcia
UVM Apple Team

Ca Accumulations

- Genetically controlled
- Season
- Cultural practices
  - Crop load
    - Fruit size
  - Position within tree
  - Number of seeds
  - Summer and winter pruning

M. E. Garcia
UVM Apple Team

- Research on foliar applications conducted mostly in the last 10 years

M. E. Garcia

UVM Apple Team

Factors influencing Ca Accumulations in apple fruit

- Cline et al., 1991 determined the seasonal pattern of Ca accumulation in ‘Delicious’ apple fruit over four years and four growing seasons (MI, VA, MA, Ontario

M. E. Garcia

UVM Apple Team

Factors influencing Ca accumulations in apple fruit

- It was determined that regardless of temperature and precipitation, apple fruit had maximum Ca uptake early in the season
  - Ca accumulation increased quadratically with most uptake early in the season, and little or no uptake three weeks before harvest

M. E. Garcia
UVM Apple Team

Factors influencing Ca accumulations in apple fruit

- In some instances, there was some Ca loss near harvest time. This loss did not appear to be associated with precipitation

M. E. Garcia
UVM Apple Team

Factors influencing Ca Accumulations in apple fruit

- Crop load
  - Large fruit has a tendency to have lower Ca concentrations
  - In a study by Ferguson et al., (1995) of 'Braeburn', it was determined that fruit from light cropping trees have lower Ca content regardless of fruit size

M. E. Garcia
UVM Apple Team

Factors influencing Ca Accumulations in apple fruit

- Fruit position
  - In a study of several apple cultivars in New Zealand, Votz et.al., 1994 investigated the effect of wood age on the mineral content of the fruit

M. E. Garcia
UVM Apple Team

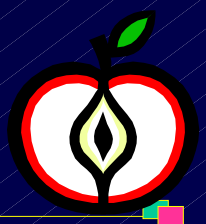
Factors influencing Ca Accumulations in apple fruit

- Role of spur leaves
- Lang and Votz (1998) conducted a study in New Zeland to determine the effect of spur leaf removal on xylem sap flow and Ca accumulation in apple fruit
  - Partial defoliation at bloom reduced the accumulation of Ca in ‘Royal Gala’

M. E. Garcia
UVM Apple Team

Factors influencing Ca Accumulations in apple fruit

- Seed number
- In a study by Tomala and Dilley (1990) in Poland, it was demonstrated that Ca concentration in ‘McIntosh’ and ‘Spartan’ but not ‘Empire’ increased with the number of seeds.



M. E. Garcia
UVM Apple Team

Ca and Fruit quality

- Low Ca levels in fruit have been associated with with poor fruit quality
  - Disorders
    - Bitter pit
  - Poor keeping quality
    - Increased rates of softening
  - Is there a relationship between the two?

M. E. Garcia
UVM Apple Team

Foliar applications and fruit firmness

- Numerous studies exist
- Most studies indicate that Ca sprays do help in controlling some disorders, but do not affect fruit firmness
  - Some results indicate higher firmness after long term storage

M. E. Garcia
UVM Apple Team

Foliar applications and fruit firmness

- A study in Spain (1998) indicated that increasing the number of applications from 6 (standard) to 13 applications did not significantly affect fruit firmness.

M. E. Garcia
UVM Apple Team

Ca foliar sprays

- Does the formulation make a difference?

M. E. Garcia
UVM Apple Team

Table 2. Some Ca materials for use on apples with label rates per acre per application, per acre per season per acre per year (1998-1999 Pennsylvania Tree Fruit Production Guide)

Product Name (Manufacturer)	% Ca	lb/gal	lb Ca/ gal or lb	Product /A/ Spray min-max	no. of application	Total product/ A/ season min-max	Total Ca/A/season (lb) min-max
Calcium Chloride (77-80% CaCl2) (many)	27.8	flake	0.28	1.8-6.2 lb	8	14.3-50 lb	4.0-14
Calcium Chloride (35% CaCl2 liquid) (many)	12.6	11.3	1.42	0.35-1.24 gal	8	2.8-9.9 gal	4.0-14
Foliar Calcium Folical (Agrimar Corp.	10.0	9.6	0.96	1 gal	6--8	6-8 gal	5.8-7.7
Nutri-Cal 8% Calcium sol'n (CSI Chemical Corp.	8.0	11.1	0.89	1-2 qt	3--8	0.75-4.0 gal	0.67-3.6
Nutra-Phos 12 (Pace Intl. LP	11.0	powder	0.11	3-10 lb	4--8	12-80 lb	2.3-8.8
Nutra-Phos 28 (Pace Intl. LP	28.0	powder	0.28	3-10 lb	4--8	12-80 lb	3.4-22.4
Nutra-Plus (Custom Chemicides	6.0	10	0.60	1-3 qt	8--11	2-8.2 gal	1.2-4.9
Sorba-Spray Ca (Pace Intl. LP	8.0	10.8	0.86	1-4 qt	4--6	1-6 gal	0.9-5.2
Sorba-Spray CaB (Pace Intl. LP	5.0	10	0.50	1-4 qt	4--6	1-6 gal	0.5-3.0
Stopit Calcium concentrate (Pace Intl. LP	12.0	10.8	1.30	1 gal	6--8	6-8 gal	7.8-10.4

Effect of Ca sprays on combined averages of fruit Ca, bitter pit and fruit quality of 'Golden Delicious' after 3 and 6 months in cold storage from orchards near Cashmere, E. Wenatchee and Wenachee, WA 1985-1988)

Quality parameters	Unsprayed check	$CaCl_2$	Mora-Leaf Ca	Ca SO_4	Nutri-Cal
Fruit size (g)	165	166	174	177	158
Finish	4.8	5.2	5.8	5.3	5.2
Color	2.8	2.7	2.3	2.6	2.8
Scald (%)	19	8	9	17	5
Firmness (lbs)	11.8	12.3	11.4	11.7	11.9
Sol. Sol (%)	13.3	13.2	12.5	12.9	13.3
Peel Ca (ppm)	0.295	0.314	0.295	0.255	0.319
Bitter pit (%)	16.7	1.0	3.9	20.2	3.5

M. E. Garcia

UVM Apple Team

To determine the price per acre per season (1998-1999 Pennsylvania Tree Fruit Production Guide)

Product A sells for $6.50 per gallon and is a liquid containing 15 % elemental calcium. The weight per gallon is 12 pounds. The label recommends 2 to 4 quarts per acre per application with eight applications suggested per season. You decide to apply 2 quarts per acre per application

Product contains 15% elemental calcium.

- 12 lb x 0.15 = 1.8 lb of elemental calcium per gal.
- You choose to apply 2 quarts (or 0.5 gal) per acre per application.
- 0.5 gal per acre per application x 8 applications per season = 4 gal of material per acre per season.
- 4 gal x 1.8 lb of elemental calcium per gal = 7.2 Ca /acre /pre season
- Our recommendation is 4.0 to 14.0 lb of elemental calcium per acre per season.
- 4.0 gal x $6.50 per gal = $26.00 per season
- $26.00 per season ÷ 7.2 lb of elemental calcium per acre per season = $3.61 elemental calcium per acre

M. E. Garcia

UVM Apple Team

To determine the price per acre per season (1998-1999 Pennsylvania Tree Fruit Production Guide)

Product B sells for $1.50 per pound and is a solid powder containing 30 % elemental calcium. The label recommends 3 to 4 pounds per acre per application with 8 applications suggested per season.

- Product contains 30% elemental calcium.
- 1 lb x 0.30 = 0.30 lb of elemental calcium per lb of material.
- You choose to apply 3.0 lb of material per acre per application.
- 3 lb per acre per application x 8 applications per season = 24 lb of material per acre per season.
- 24 lb x 0.30 = 7.2 lb of elemental calcium per acre per season.
- Our recommendation is 4.0 to 14.0 lb of elemental calcium per acre per season.
- 24 lb x $1.50 per lb = $36.00.
- $36.00 per season ÷7.2 lb of elemental season = $5. 00 elemental calcium per acre.

M. E. Garcia

UVM Apple Team

Conclusion

- Research reinforces previous research
  - Ca foliar sprays help prevent some fruit disorders
  - Ca foliar sprays do not seem to increase fruit firmness

M. E. Garcia
UVM Apple Team

Conclusion

- Conduct cultural practices that promote Ca uptake and distribution
  - Irrigation
  - Summer pruning
  - Control N fertilization
- When applying foliar spays
  - Determine the % Ca
  - Buy the cheapest

M. E. Garcia
UVM Apple Team

Calcium and Boron

- Boron (B) is an essential trace element
- Apple trees have high B requirements (25-45 ppm)
- B is important
  - Pollen germination
  - Pollen tube grwoth
  - Successful fruit set
  - Formation of feeder roots

M. E. Garcia
UVM Apple Team

Boron

- Both low and high concentrations cause poor fruit quality
- Low B
  - Short storage life: higher susceptibly to storage breakdown
  - Fruit deformities
- High B
  - Higher incidence of internal disorders
  - Watercore and internal breakdown

M. E. Garcia
UVM Apple Team

Boron

- In a study conducted in Poland (1999) four B applications were compared

1. Soil application (2 g / tree)
2. Spray application 3 x before bloom (0.67 g per tree)
3. Spray application after bloom 3 x (0.67 g per tree)
4. No B

M. E. Garcia
UVM Apple Team

Boron

- Results:
- All treatments except for control increased B concentration in apple fruit
  - Highest concentration was found in fruits sprayed after bloom and soil applications
- B sprays after bloom decreased fruit weight, fruit firmness, but increased fruit set, yield, and Ca concentration

M. E. Garcia
UVM Apple Team

Foliar applications and fruit firmness

- Why not depend on drenches?
  - Ca deficiency problems in the orchard as well as after harvest
  - Post harvest treatments not always feasible

M. E. Garcia
UVM Apple Team