Improving potato tuber quality and mitigating stress impact by calcium nutrition:

Jiwan P. Palta

Department of Horticulture

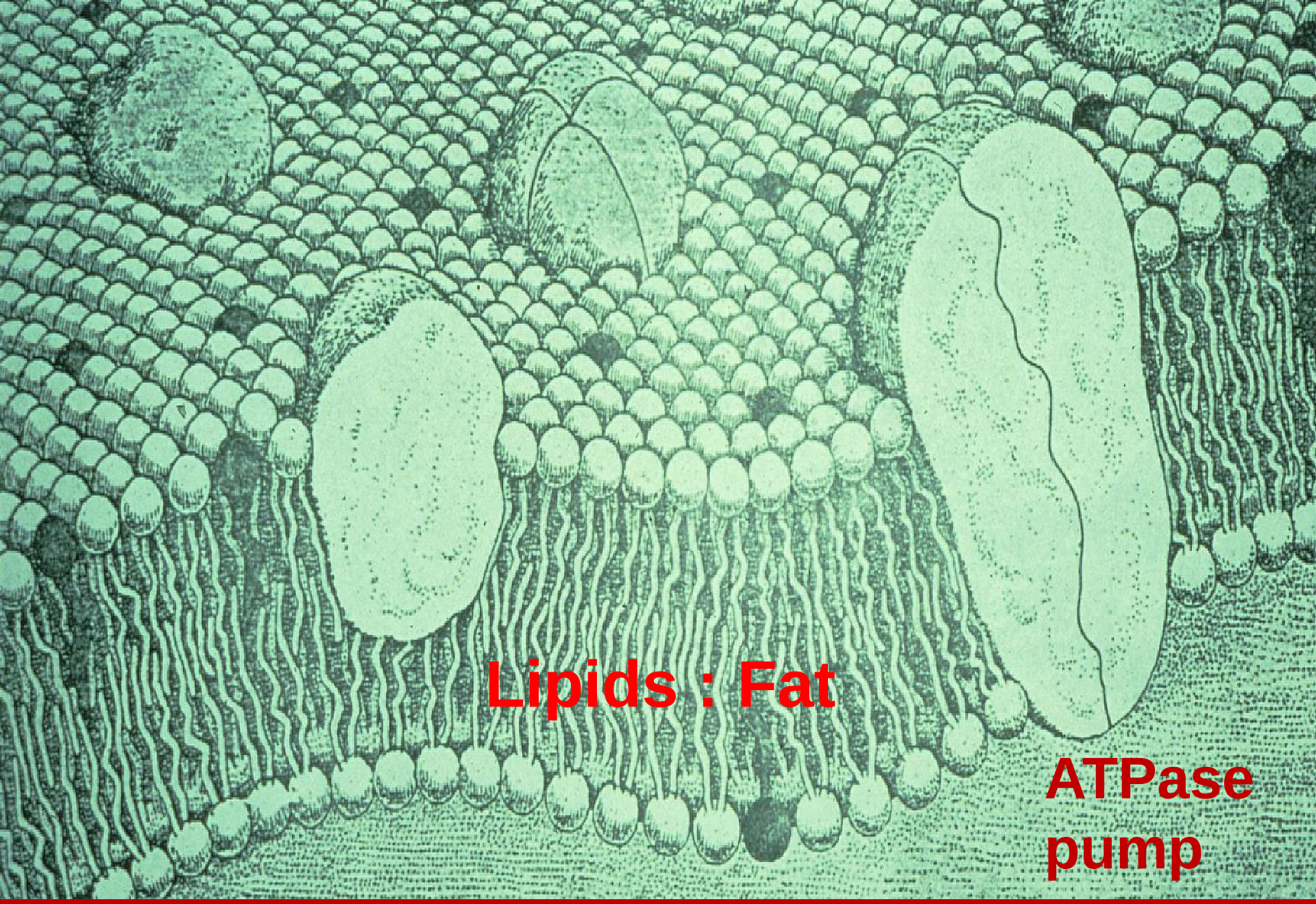
University of Wisconsin-Madison USA

Roles of Calcium in Plant

A. Physical and Chemical

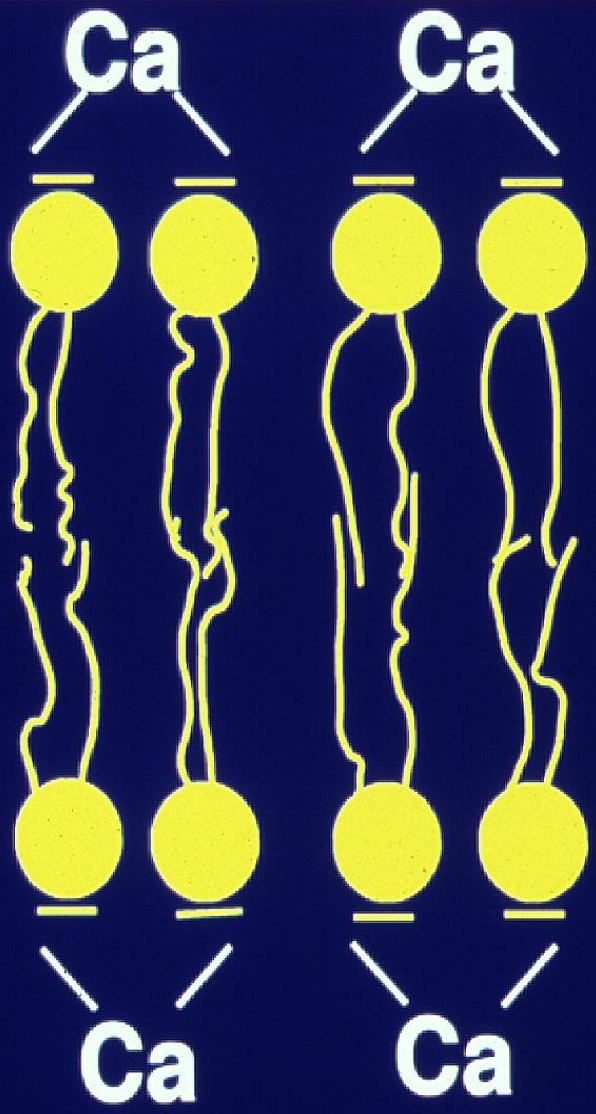
1. Cell wall strength
2. Membrane health
3. Cation Balance

B. Metabolic: Secondary Messenger



Palta 2012. in Combating Climate Change
Tatlor & Francis 237-269

Cell Wall



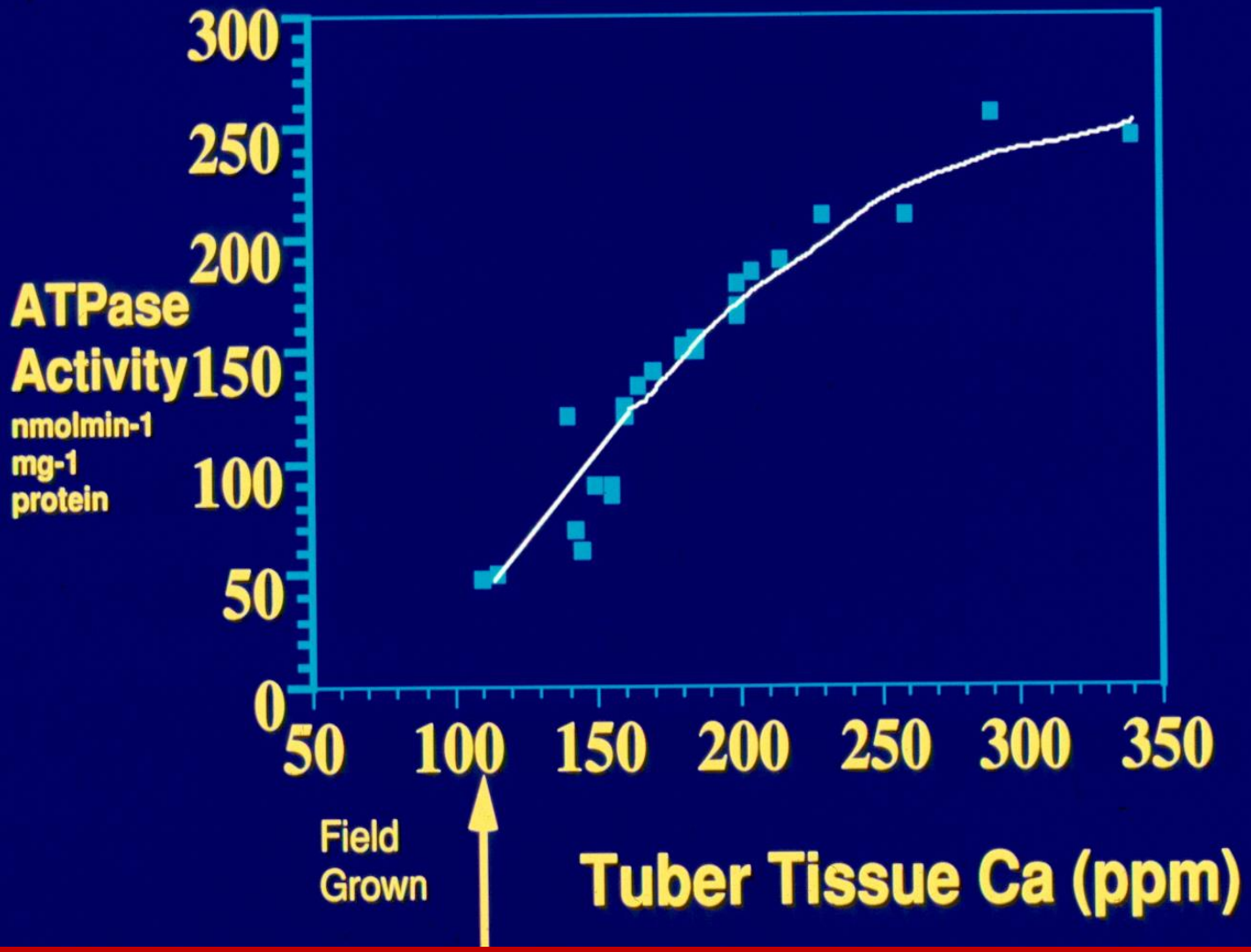
Plant Cell Membranes

Lipid Bilayer Structure

Stabilized by Calcium

Palta 2012. in Combating Climate Change
Tatlor & Francis 237-269

Plasma Membrane Pump Activity



Calcium as a regulator

For Example: Calcium can regulate tuberization signal

- Low Calcium promotes tuberization
- High Calcium inhibits tuberization

Ozgen and Palta 2005. HortSci. 40:102-105

Calcium nutrition

Part 1: Potato quality

Part 2: Mitigating stresses (cold, heat, salinity)

Early Research showed (early 80`s)

Potatoes with higher Calcium

Store better
Less bacterial soft rot

Gypsum and Lime was tried
Did not give consistent results

I joined the University in 1982

Early 80’s all fertilizer applied by tractors (solid products)

Mid-June last hilling

Last time to apply the fertilizer


Our soils: Sandy
Irrigated 2 cm water
Every other day


Top portion of the hill where tubers are is washed and nutrients can be leached by the time tubers are growing

Tuber

- **Botanically stem tissue**
- **5 times less calcium than stem**
- **Naturally calcium defficient**

Potato Tubers Naturally Deficient in Calcium

Reasons:

- Calcium moves with water
- Very little water moves to tuber

How is calcium taken up by the potato tuber ?

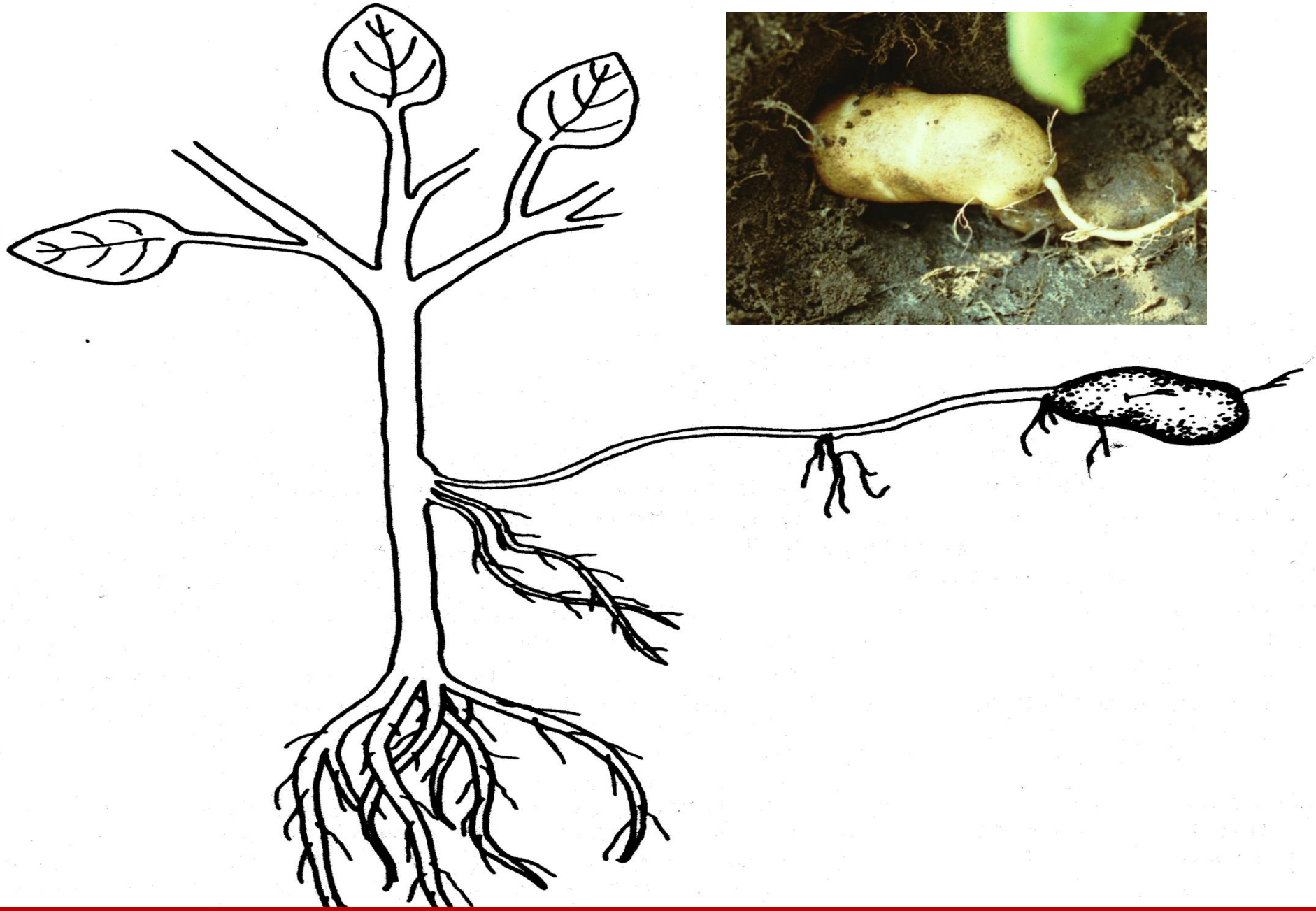
Since calcium moves with water…

From where does tuber gets its water ?

Theory :

Everything tuber needs comes from the top ?

Kratzke and Palta, 1985.
Am Potato J. 62:227-236



Kratzke and Palta, 1985.
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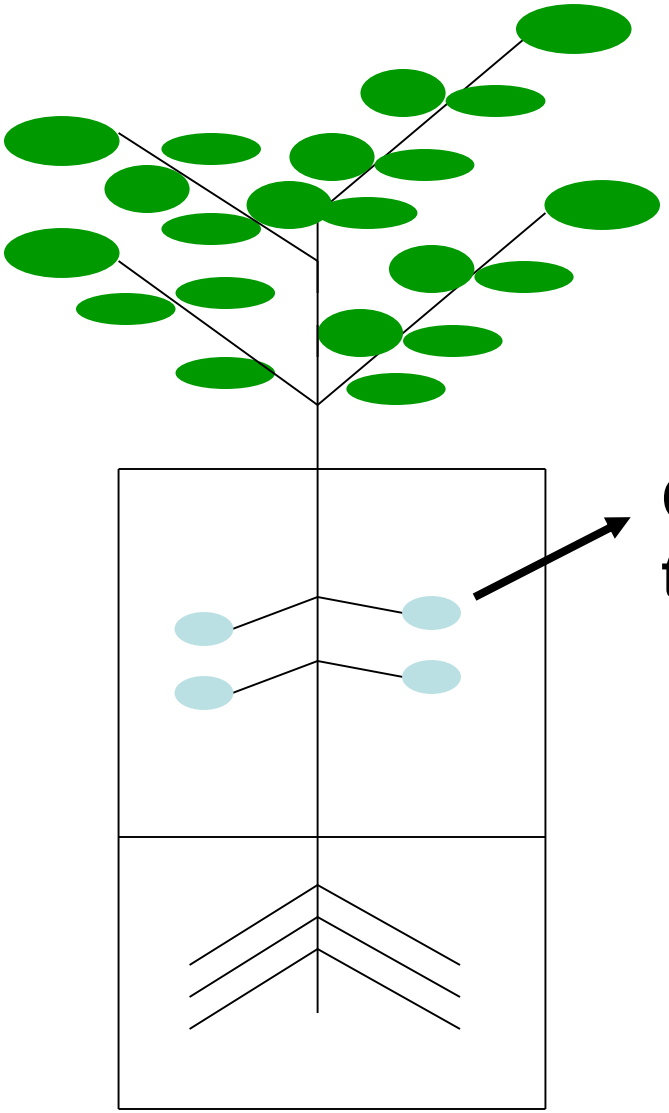
Am Potato J. 62:227-236

Ca 45 Added in the water

Busse and Palta, 2006.
Physiologia Plantarum 128:313-323

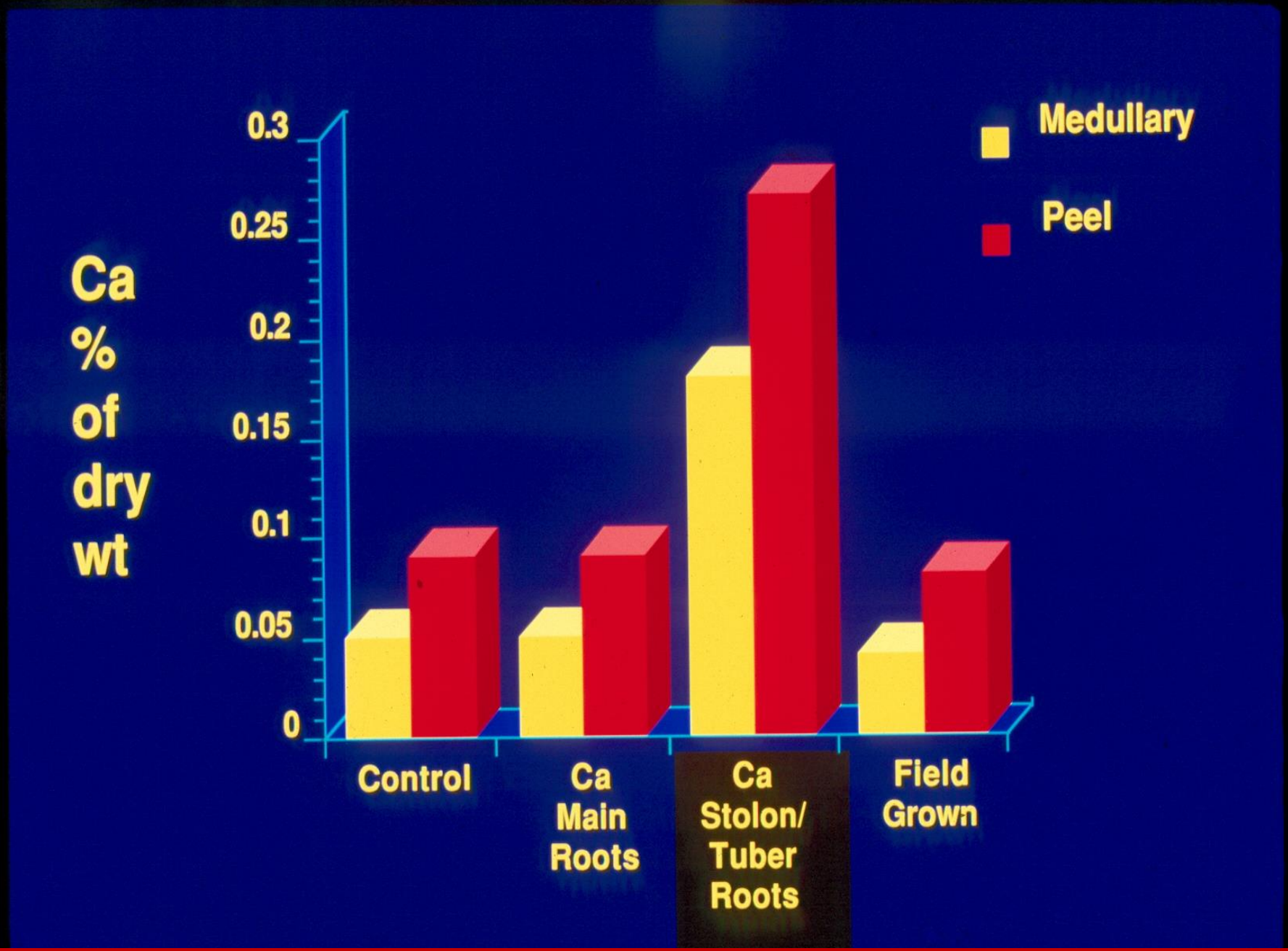
Busse and Palta, 2006.
Physiologia Plantarum 128:313-323

Split pot study



Ca taken up by the tubers from the surrounding soil

Kratzke and Palta, 1986.
HortScience 21:1022-1024



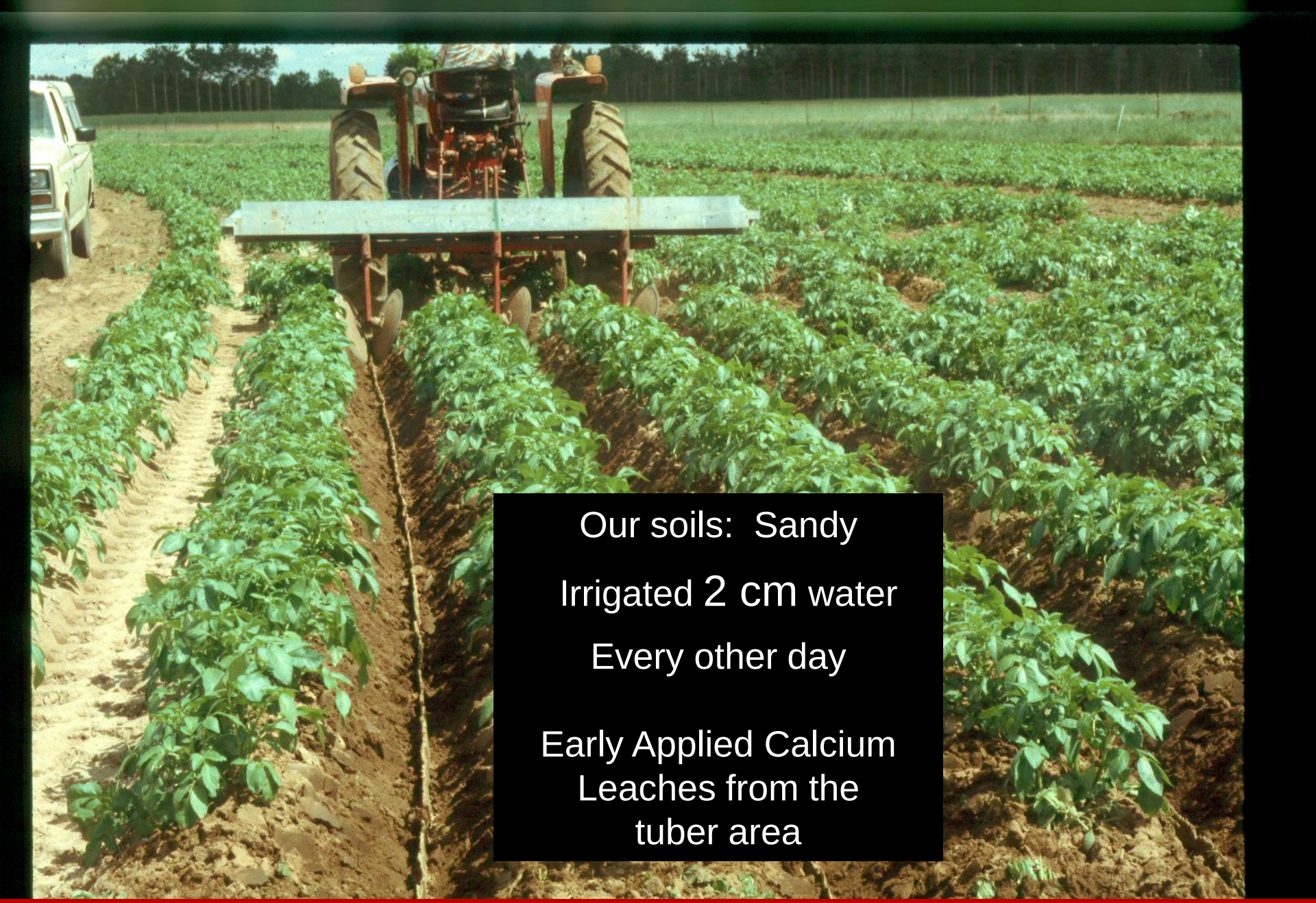
Kratzke and Palta, 1986.
HortScience 21:1022-1024

Tuber an underground plant

Implications

A. Placement (around the tuber area)

B. Timing (bulking): Later in season


Our soils: Sandy
Irrigated 2 cm water
Every other day
Early Applied Calcium
Leaches from the
tuber area

Put calcium with water during the tuber growth period

Water soluble calcium fertilizer

Calcium nitrate

Calcium chloride

Genesis of liquid fertilizers

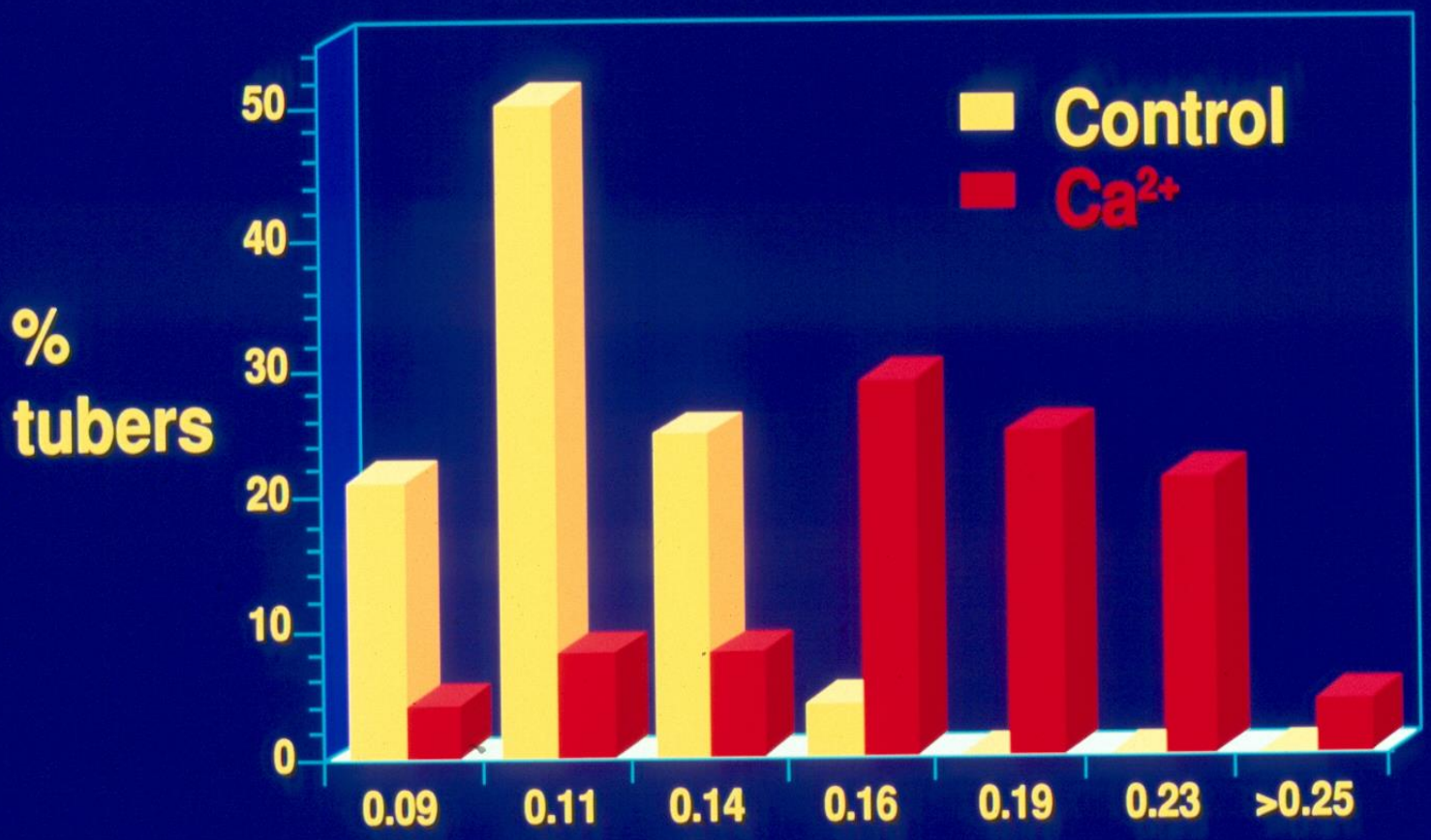
↓

Idea: Put calcium in water during the tuber bulking period

(Late June-August)

Put calcium with water during the tuber growth period

Tuber Ca^{2+}



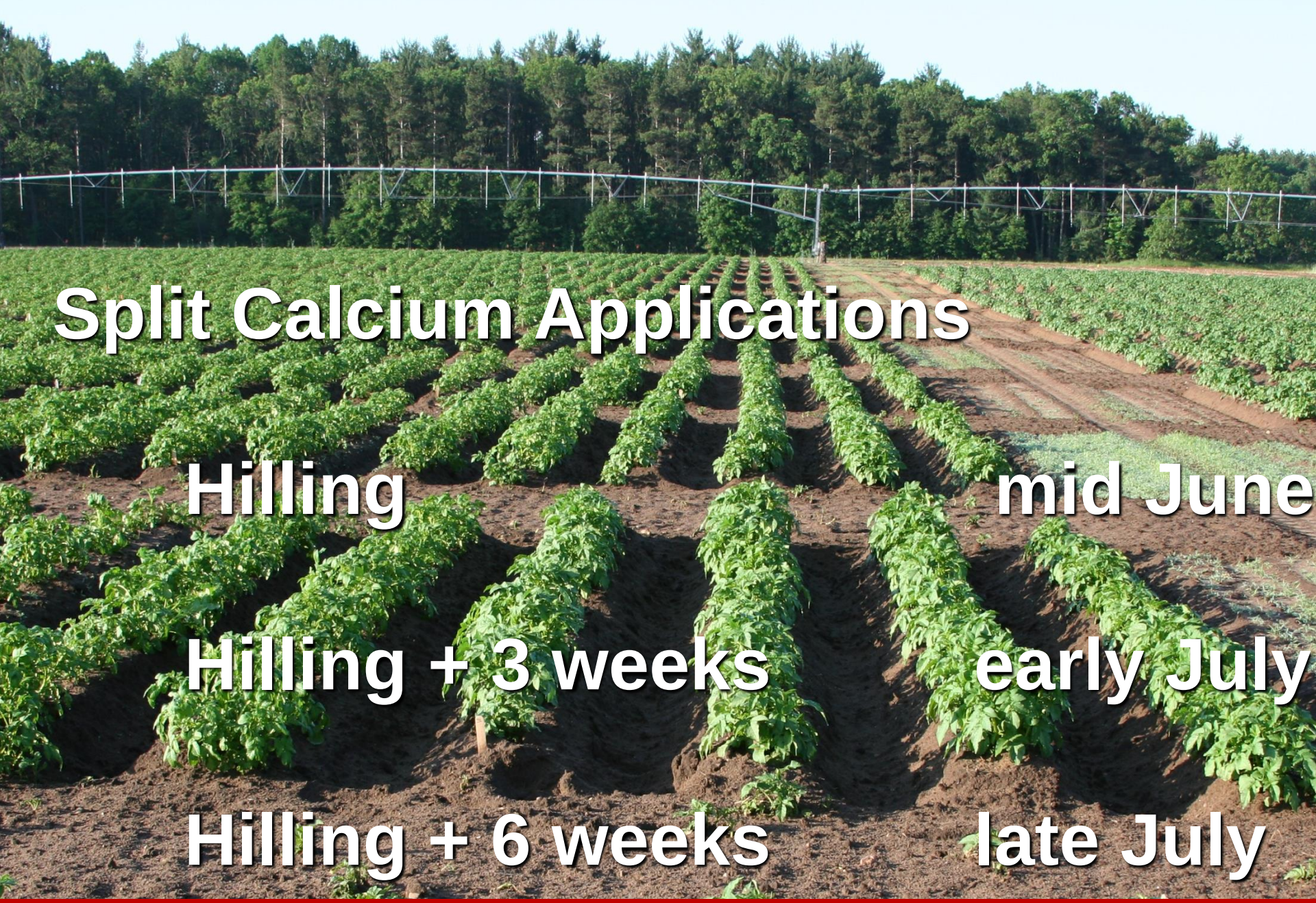
Soil Test ~ 1000 kg/ha

Kleinhenz, Palta, Gunter, and Kelling, 1999.
J. Amer. Soc. Hort. Sci. 125:498-506

New concept in potato nutrition

Spoon-feeding with Ca

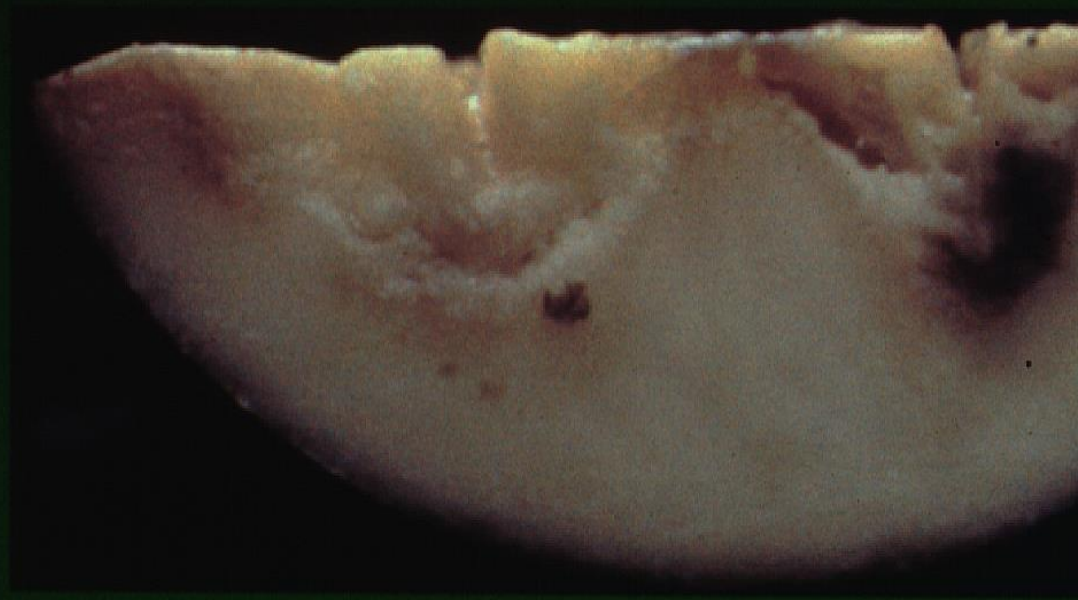
during bulking

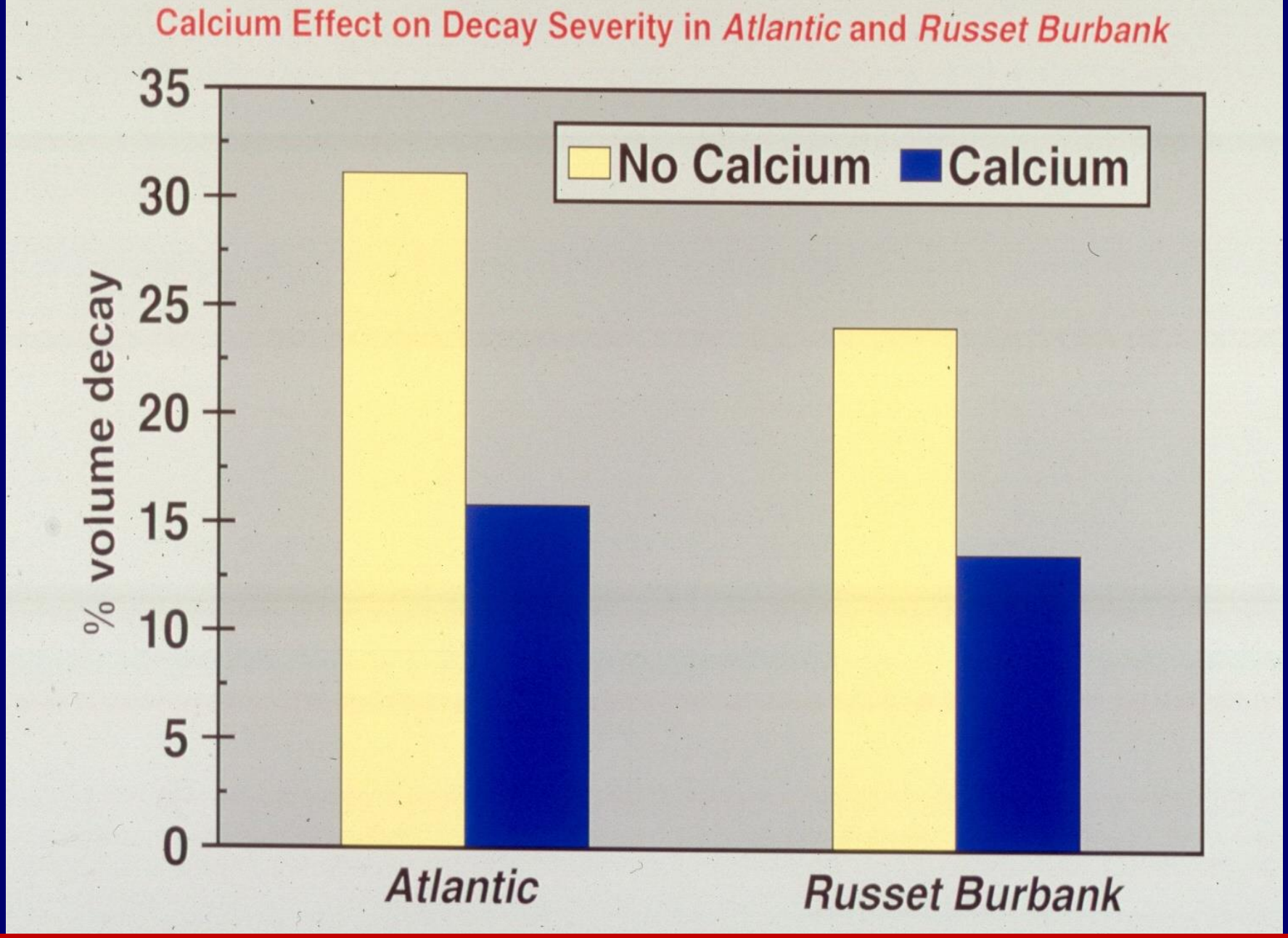

Split Calcium Applications
Hilling
mid June
Hilling + 3 weeks
early July
Hilling + 6 weeks
late July

Precise Nutrient Application

Is there benefit?

Reduce Storage Rot




Calcium Effect on Decay Severity in Atlantic and Russet Burbank
No Calcium
Calcium
% volume decay
35
30
25
20
15
10
5
0
Atlantic
Russet Burbank

Reduce Internal Disorders

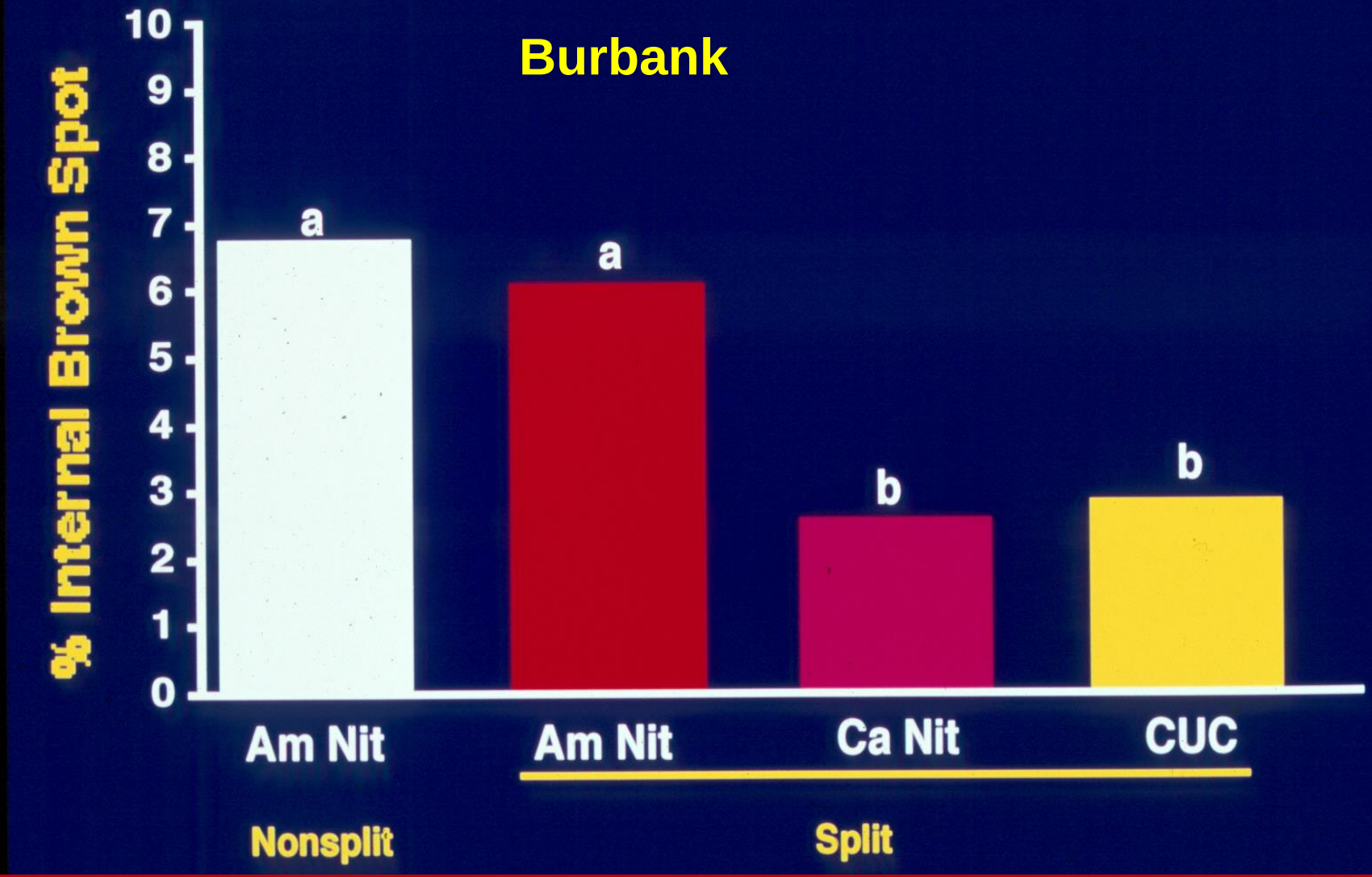
Internal Brown Spot

Hollow Heart

Brown Center

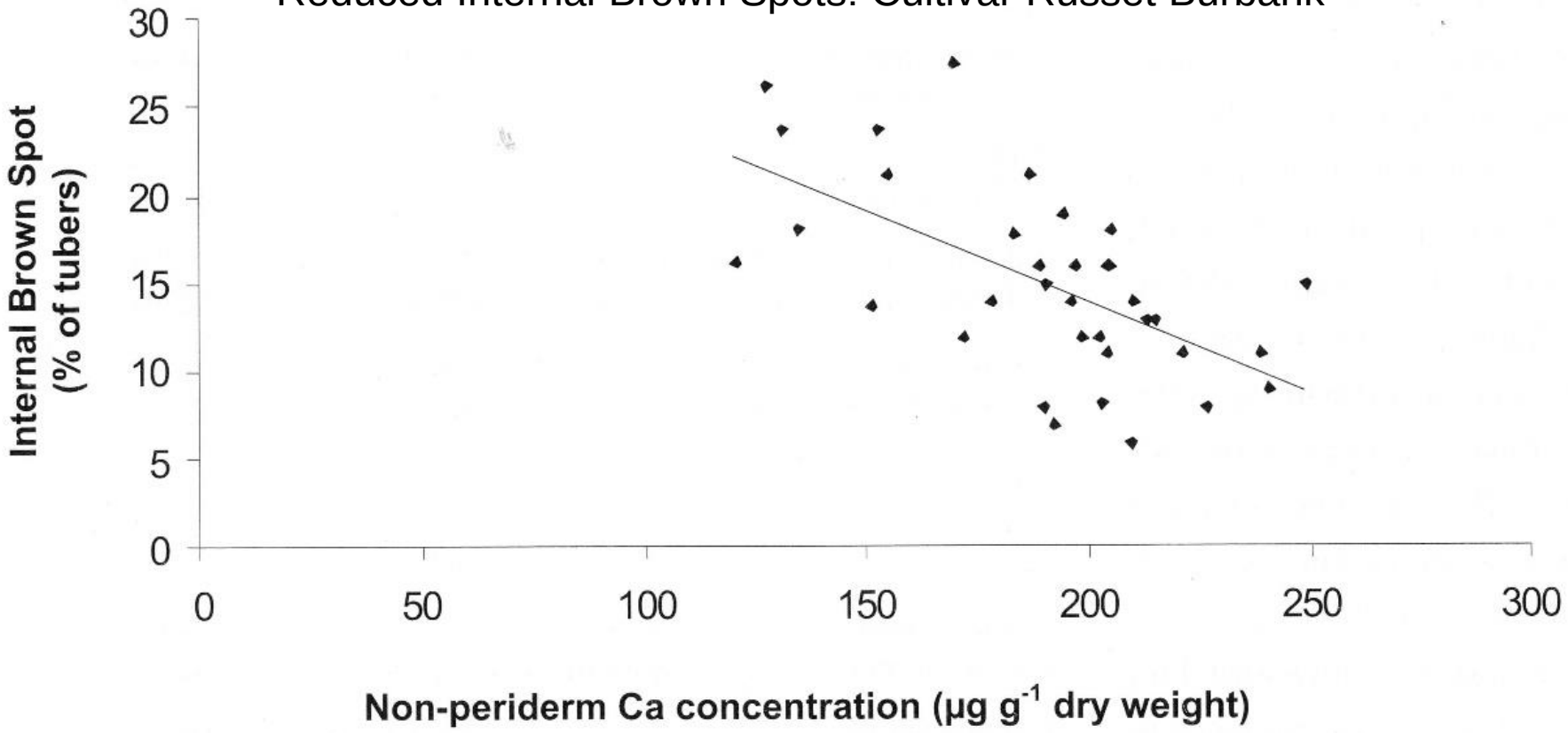
% Internal Brown Spot

LSD(α=0.05)



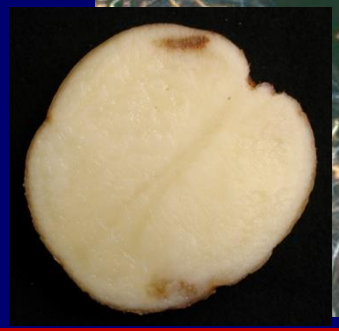
Ozgen, Karlsson, and Palta, 2006.
Amer. J. of Potato Res. 83:195-204

Reduced Internal Brown Spots: Cultivar Russet Burbank

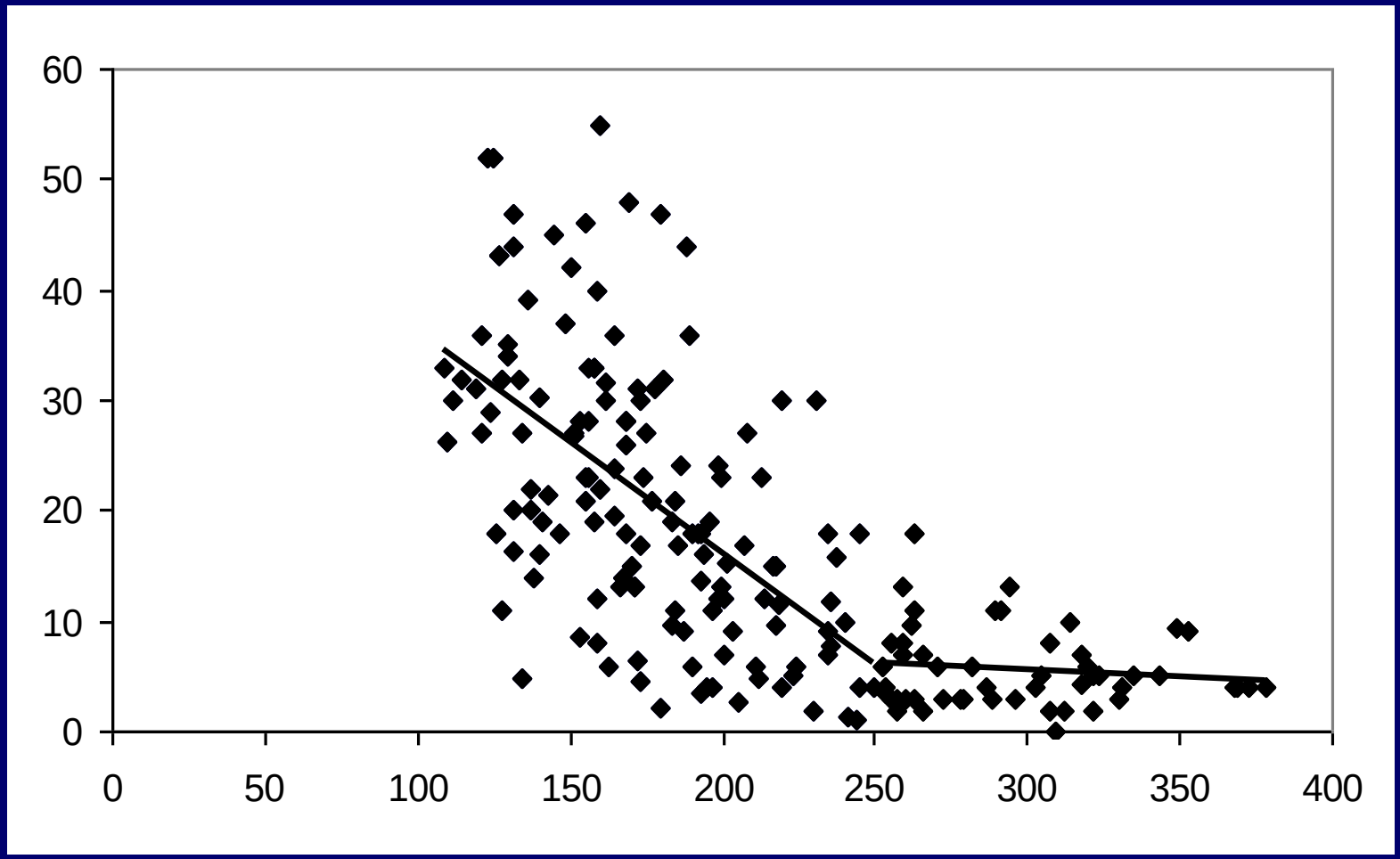


Ozgen, Karlsson and Palta 2006.
Amer. J. Potato Res. 83:195-204

Bruising occurs as tubers tumble and bounce during harvest

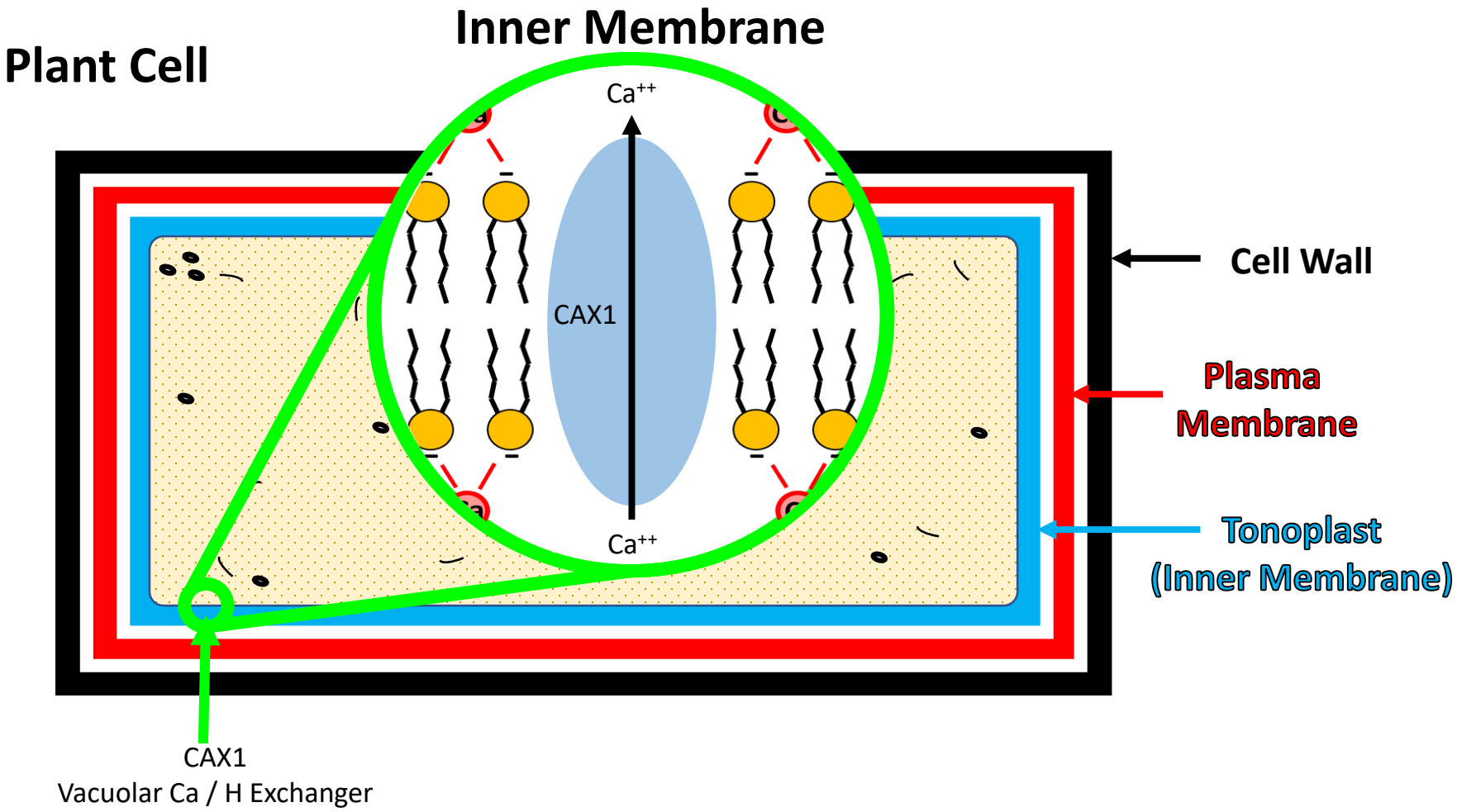


Incidence of mechanical bruising



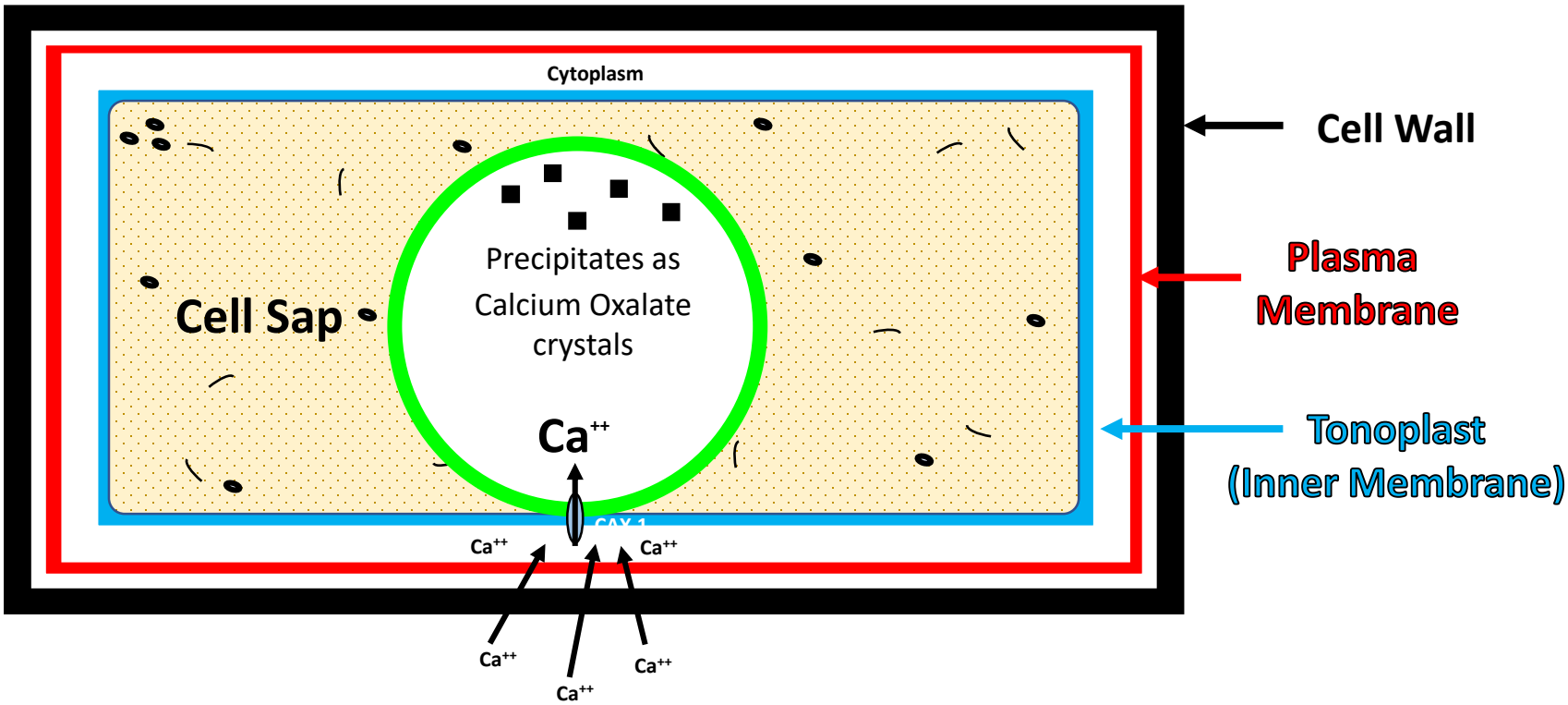
-Data from five cultivars and three seasons 1999, 2000, and 2001.

Karlsson, Crump, and Palta, 2006.
HortScience 41:1213-1221



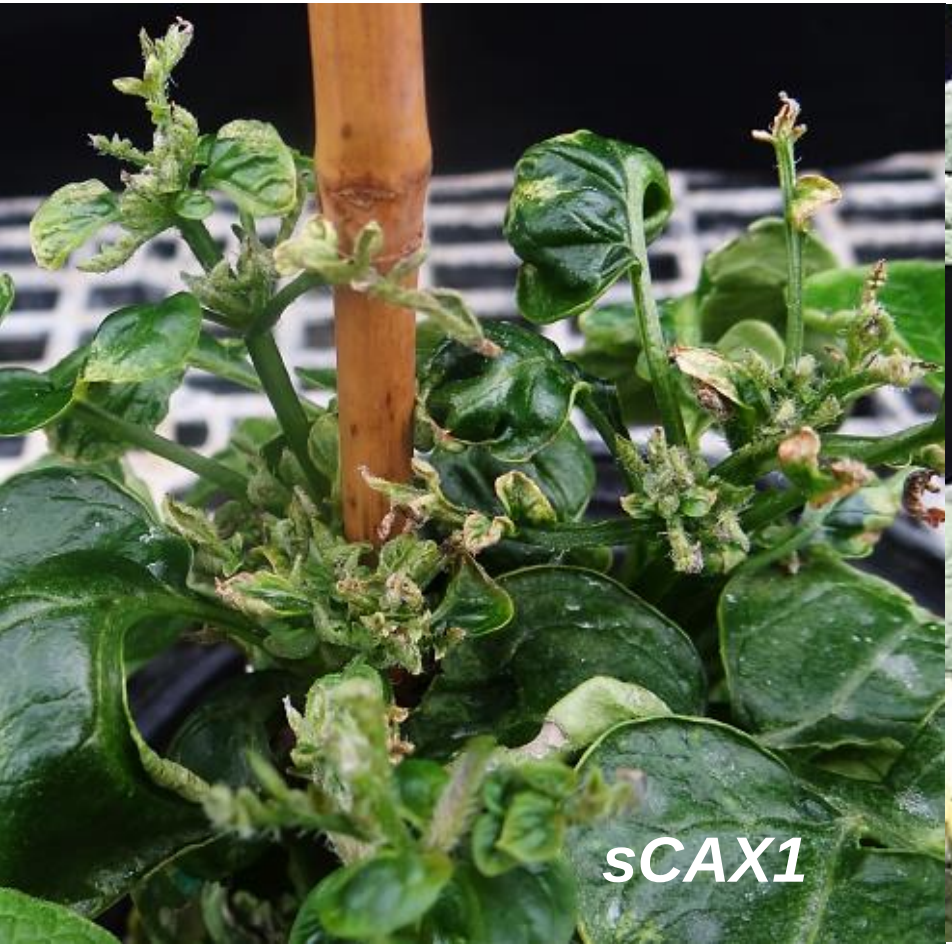
Zorrilla, Schabow, Chernov, and Palta, 2019.
Crop Science 59:176-189

Plant Cell



Overexpressing s*CAX 1 in potato results in calcium deficiency symptoms*

Zorrilla, Schabow, Chernov, and Palta, 2019.
Crop Science 59:176-189



Zorrilla, Schabow, Chernov, and Palta, 2019.
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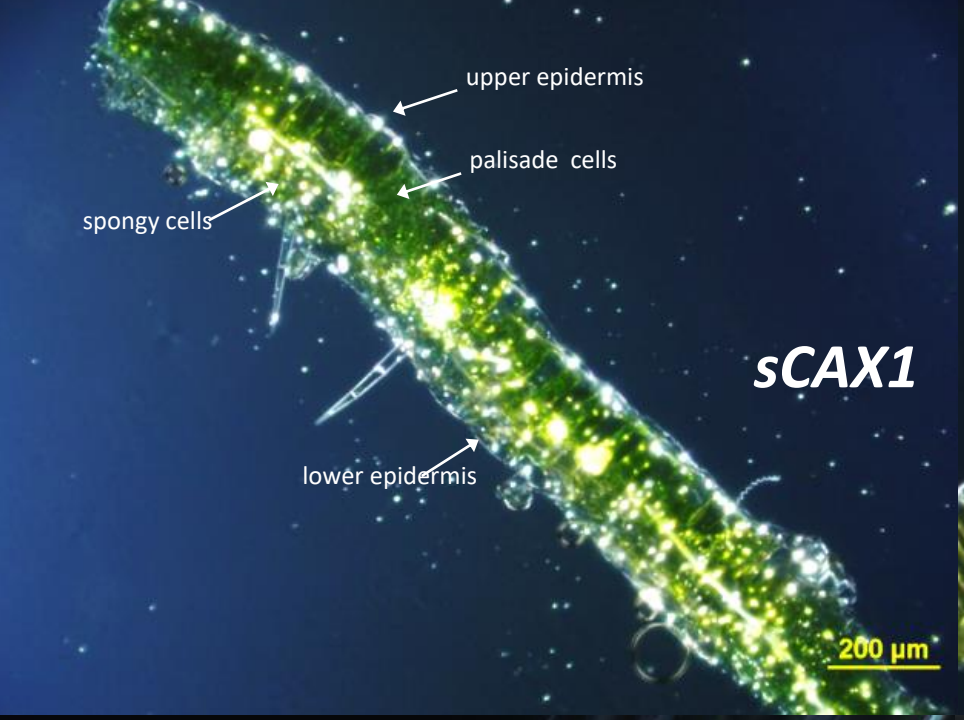

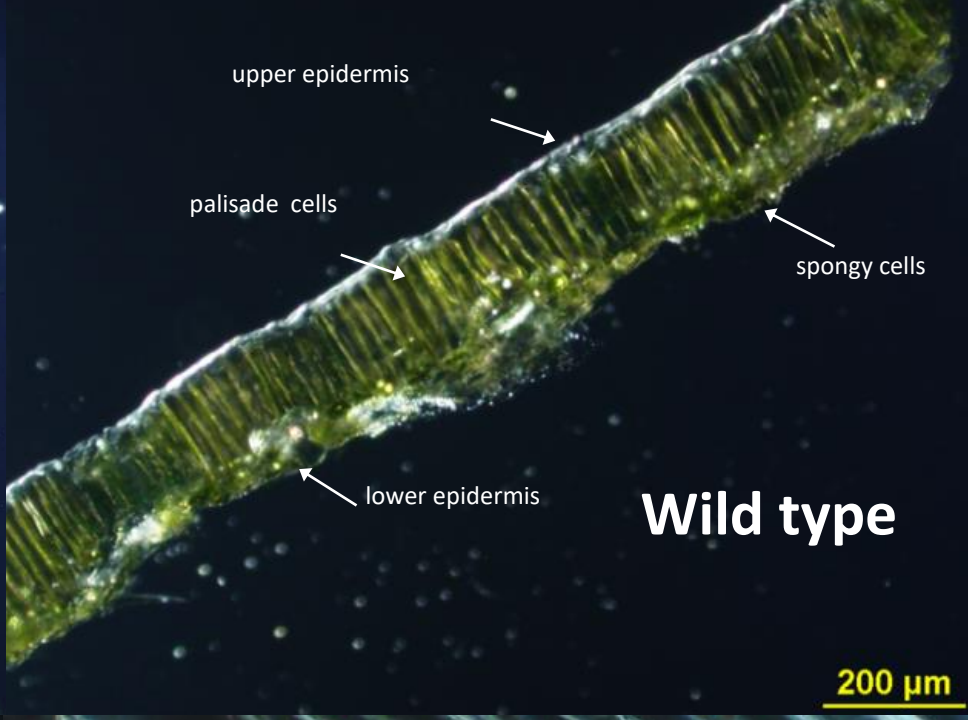

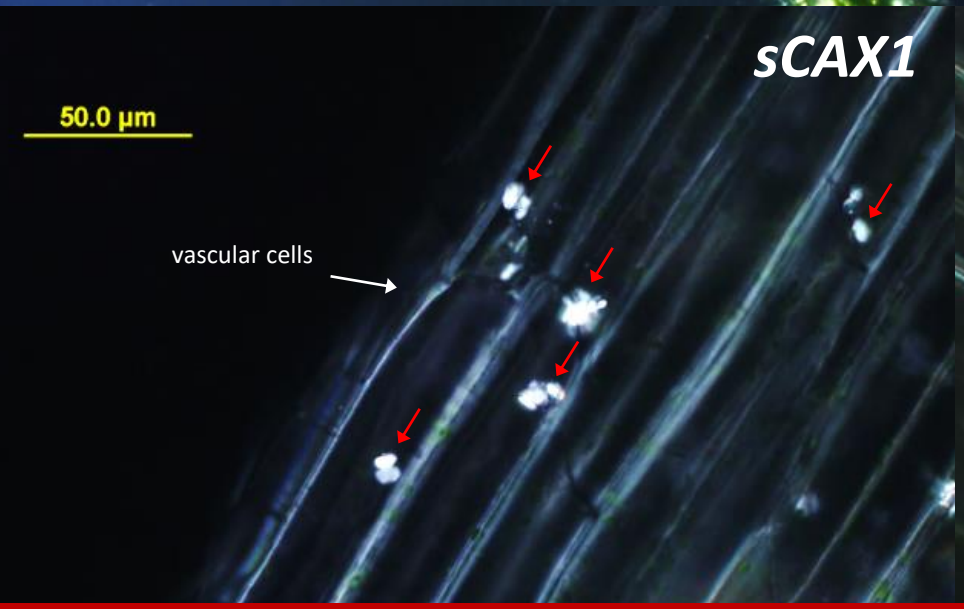

Zorrilla, Schabow, Chernov, and Palta, 2019.
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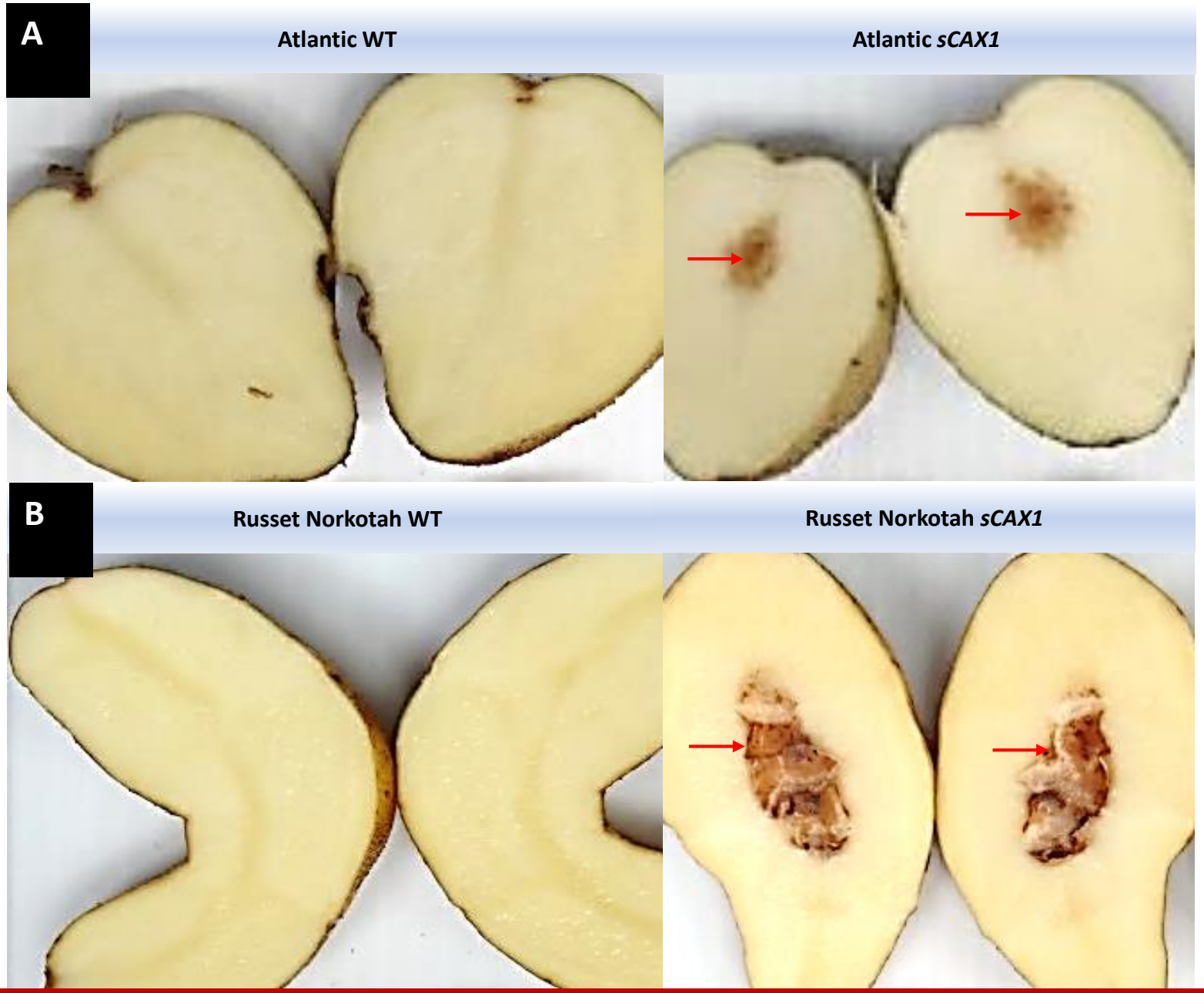
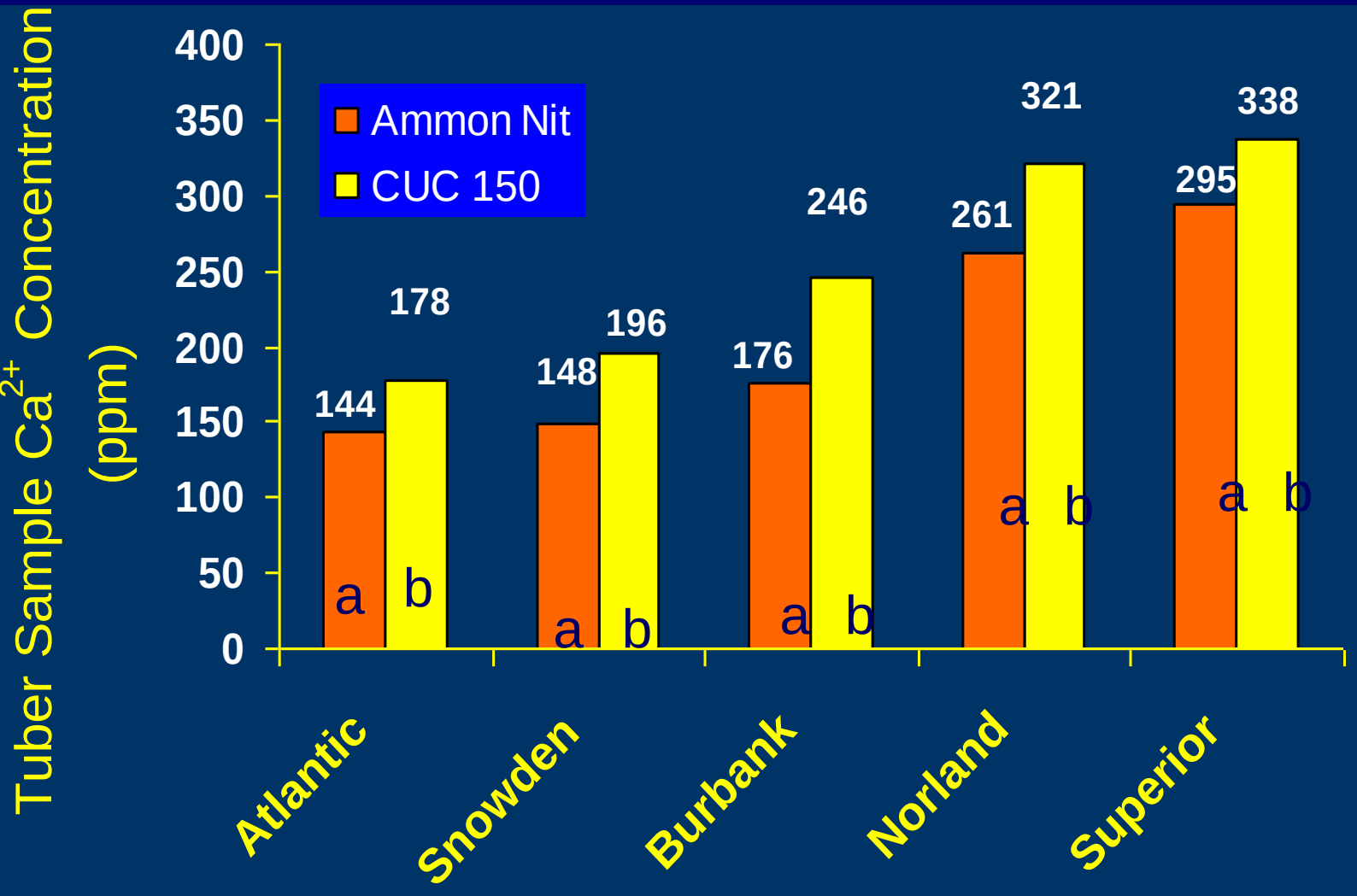


Zorrilla, Schabow, Chernov, and Palta, 2019.
Crop Science 59:176-189

Tuber tissue calcium : A genetic trait

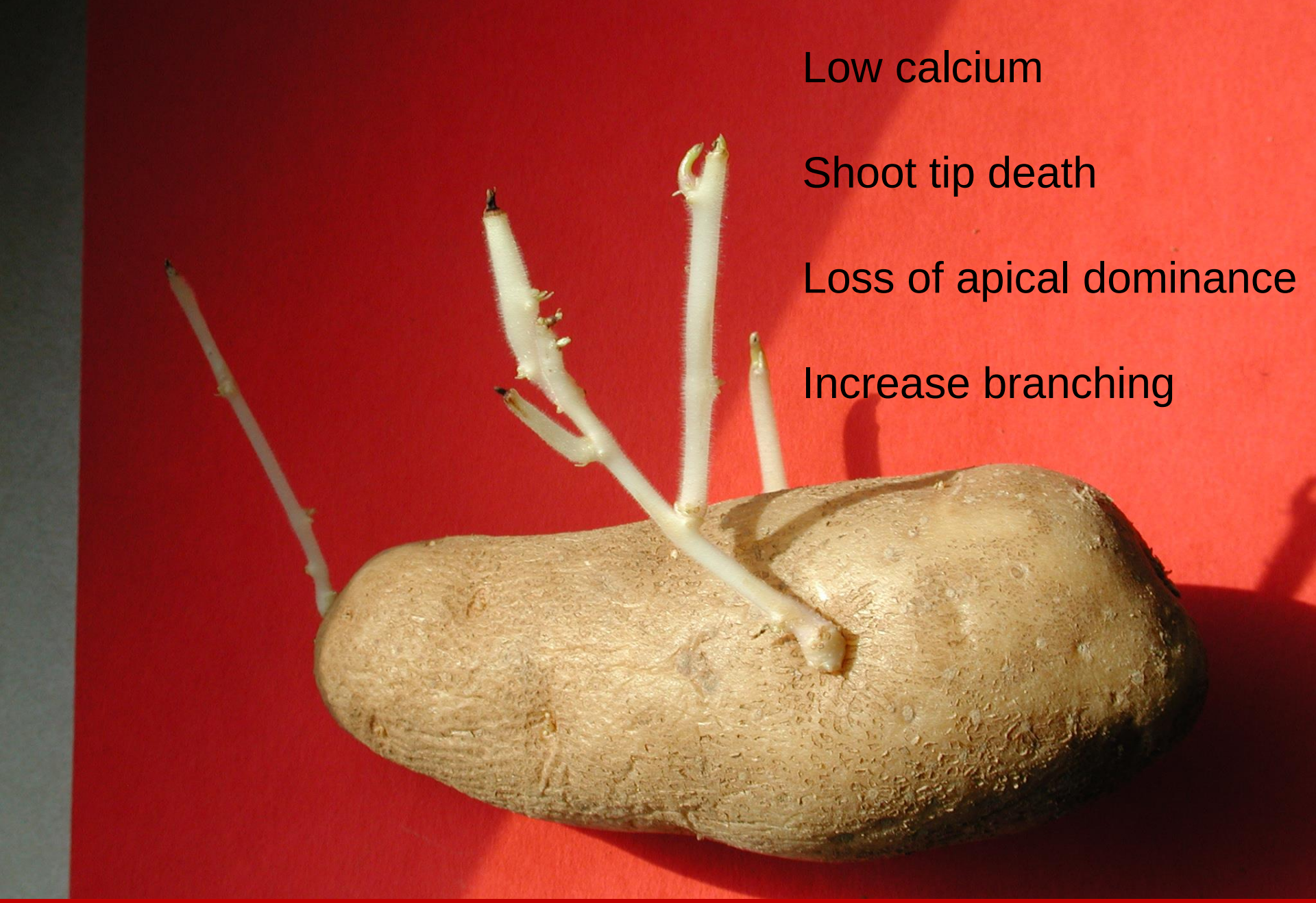


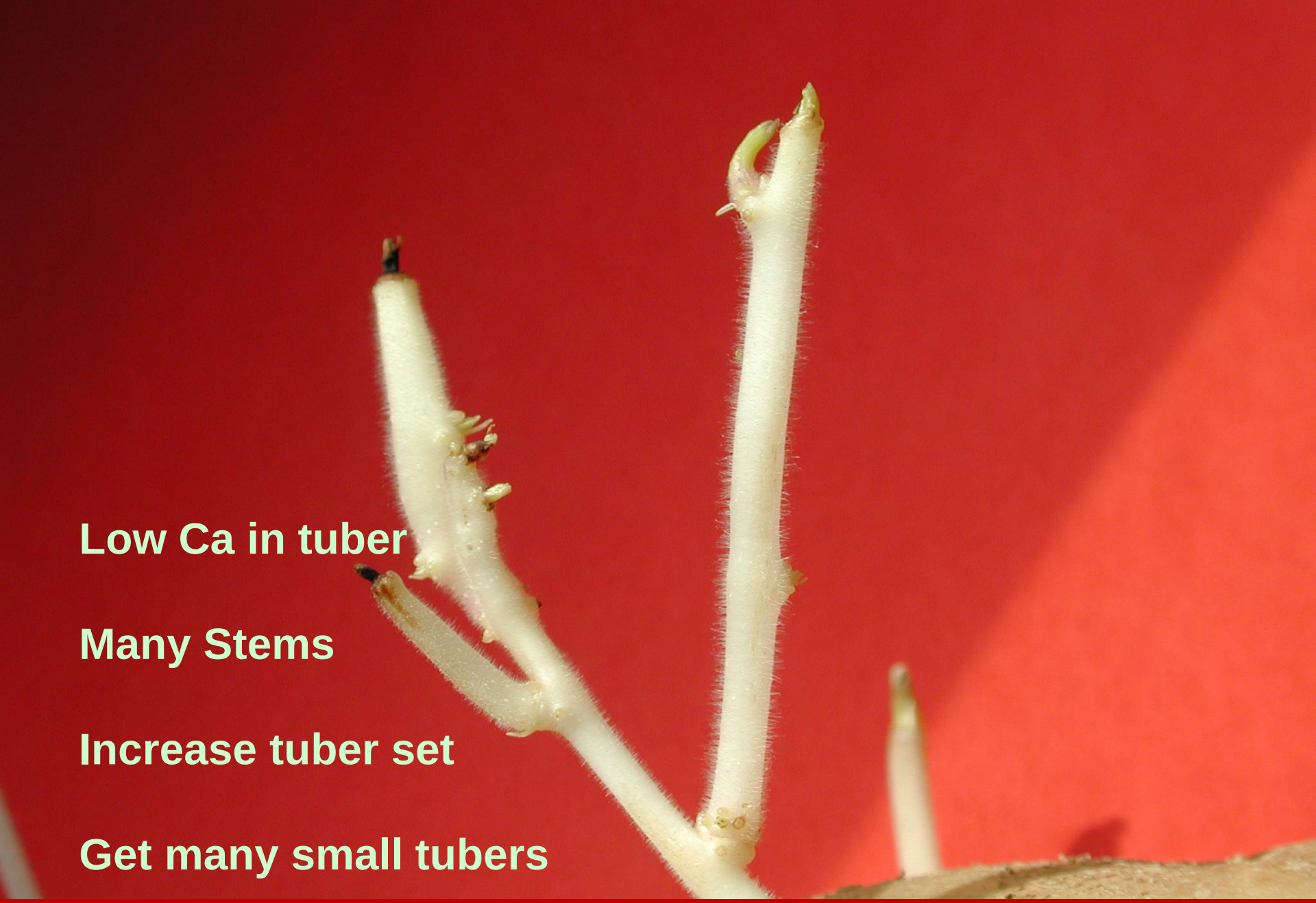
Karlsson, Crump, Palta, 2006.
HortScience 41:1213-1221

Calcium and Seed Piece Quality

Lack of calcium linked To Sprout sub-apical necrosis

Dostal, 1943. Phytopathologishe. Zeitschrift 14:484-496.
Dyson and Digby, 1975. Potato Res. 18:290-305


Low calcium
Shoot tip death
Loss of apical dominance
Increase branching

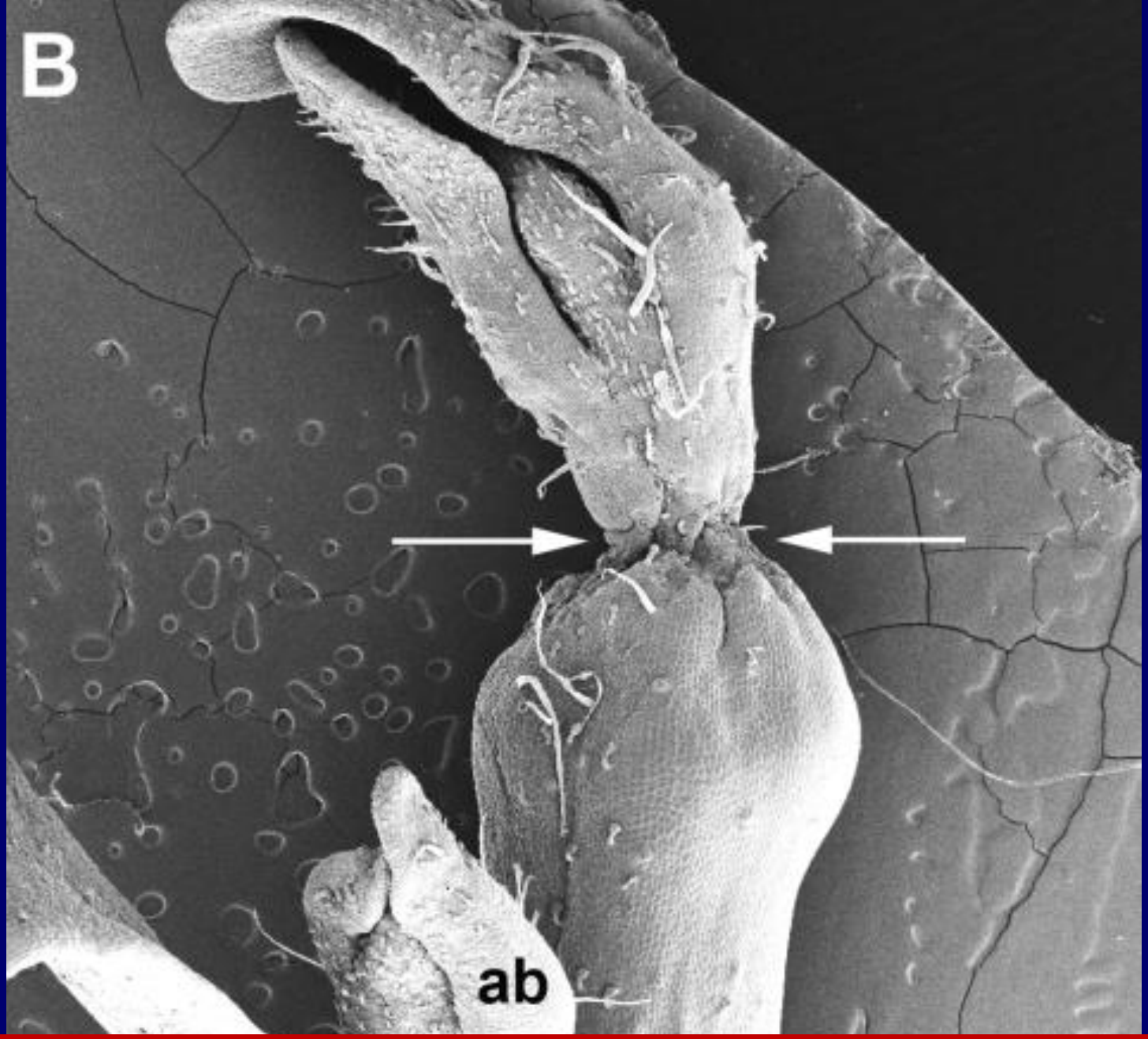


Low Ca in tuber

Many Stems

Increase tuber set

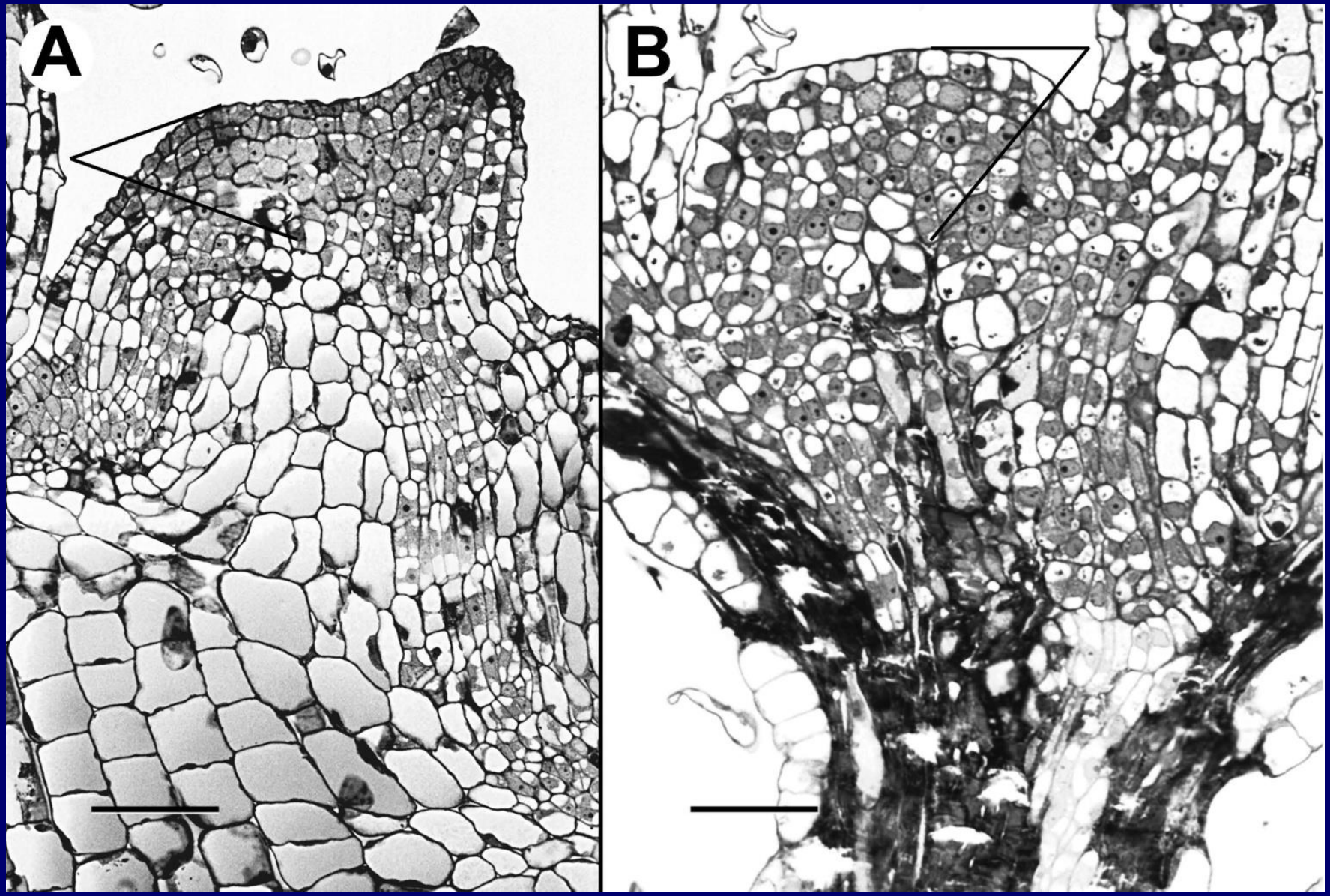
Get many small tubers



Busse, Ozgen, Palta, 2008.
J. Amer. Soc. Hort. Sci. 133:653-662

Normal Shoot Tip

Calcium deficient, injured shoot tip



Busse, Ozgen, Palta, 2008.
J. Amer. Soc. Hort. Sci. 133:653-662

Calcium
Very important
in
Seed Piece Quality

Important considerations:

Soil

pH, texture, organic matter, CEC,

% Ca base saturation, other minerals N, P, K)

Solubility of calcium product

Irrigated or not

Calcium nutrition

Part 1: Potato quality

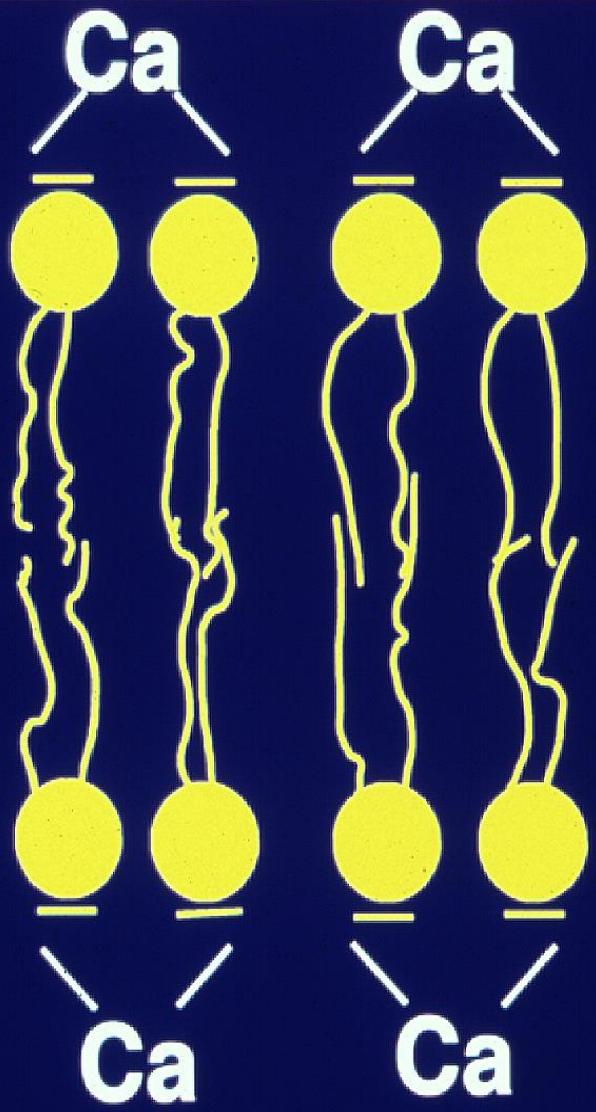
Part 2: Mitigating stresses (cold, heat)

Mitigation of Heat, Cold and Salinity Stresses

by

Calcium

Cell Wall



Plant Cell Membranes

Lipid Bilayer Structure

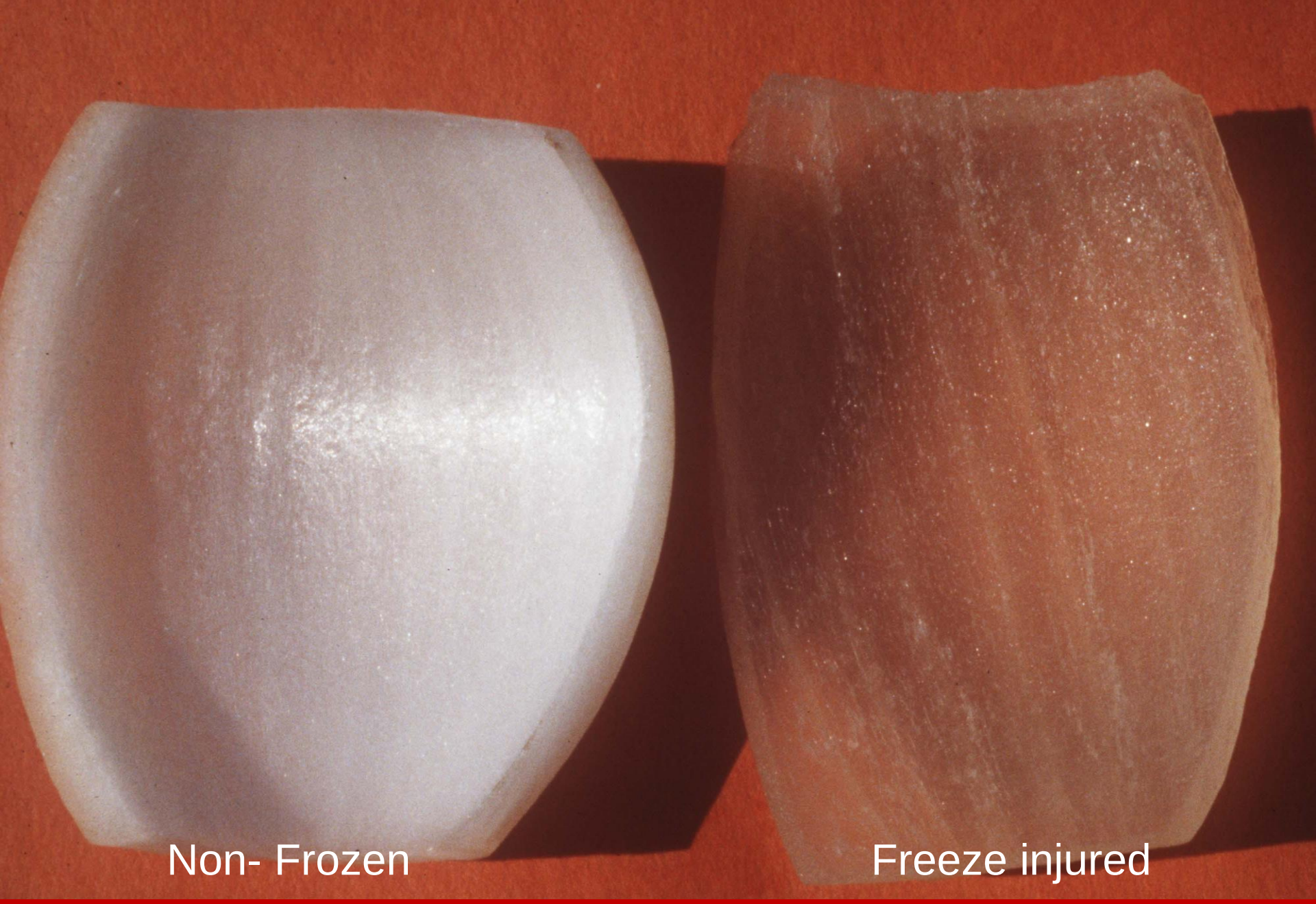
Stabilized by Calcium

Palta 2012. in Combating Climate Change
Tatlor & Francis 237-269

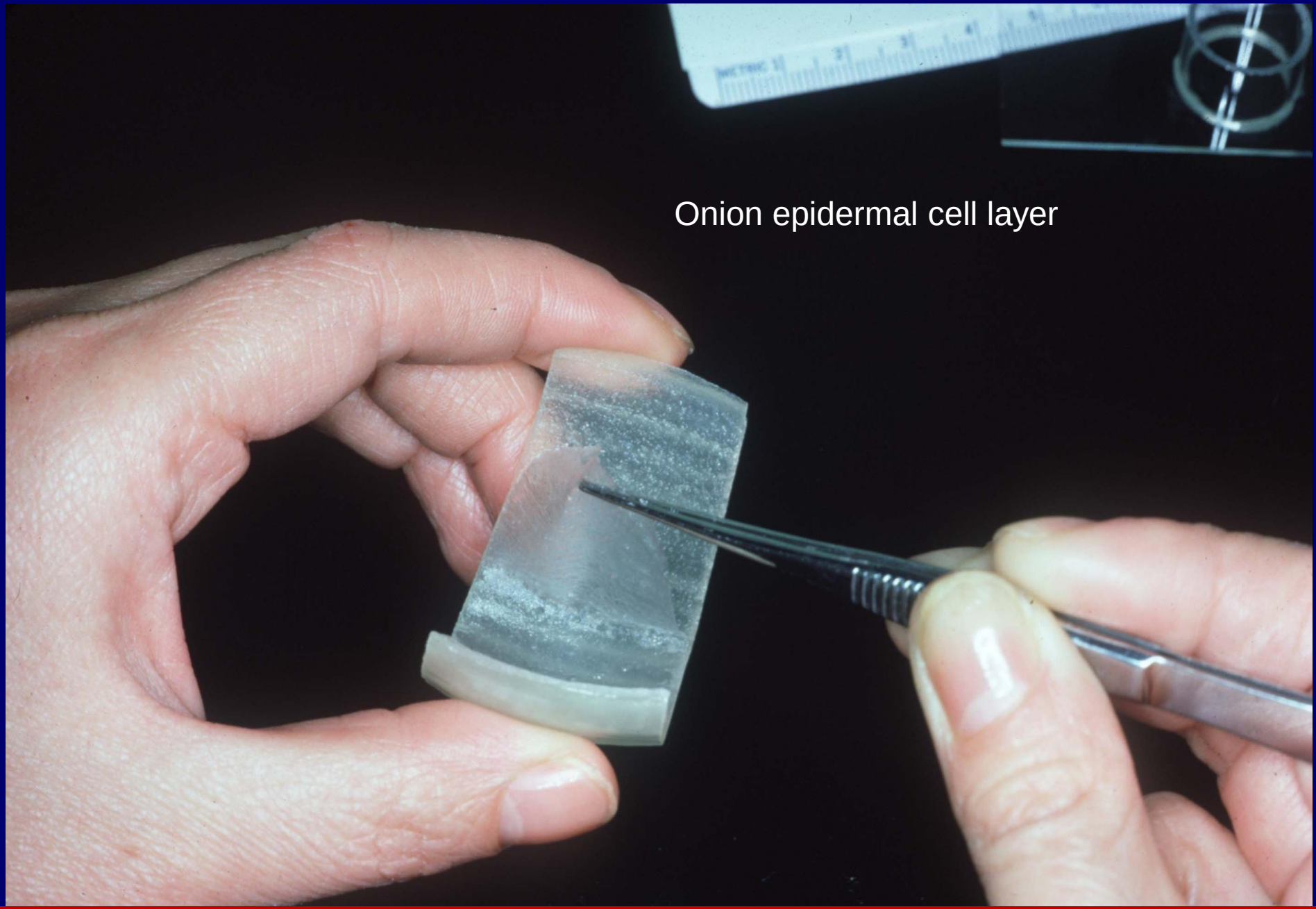
- **Cold stress : Lipids solidfy**
- **Heat Stress : Lipids melt**
- **Results in**

•Loss of membrane calcium
•Membrane weekness
•Injury

Arora and Palta, 1988.
Plant Physiol. 87:622-628



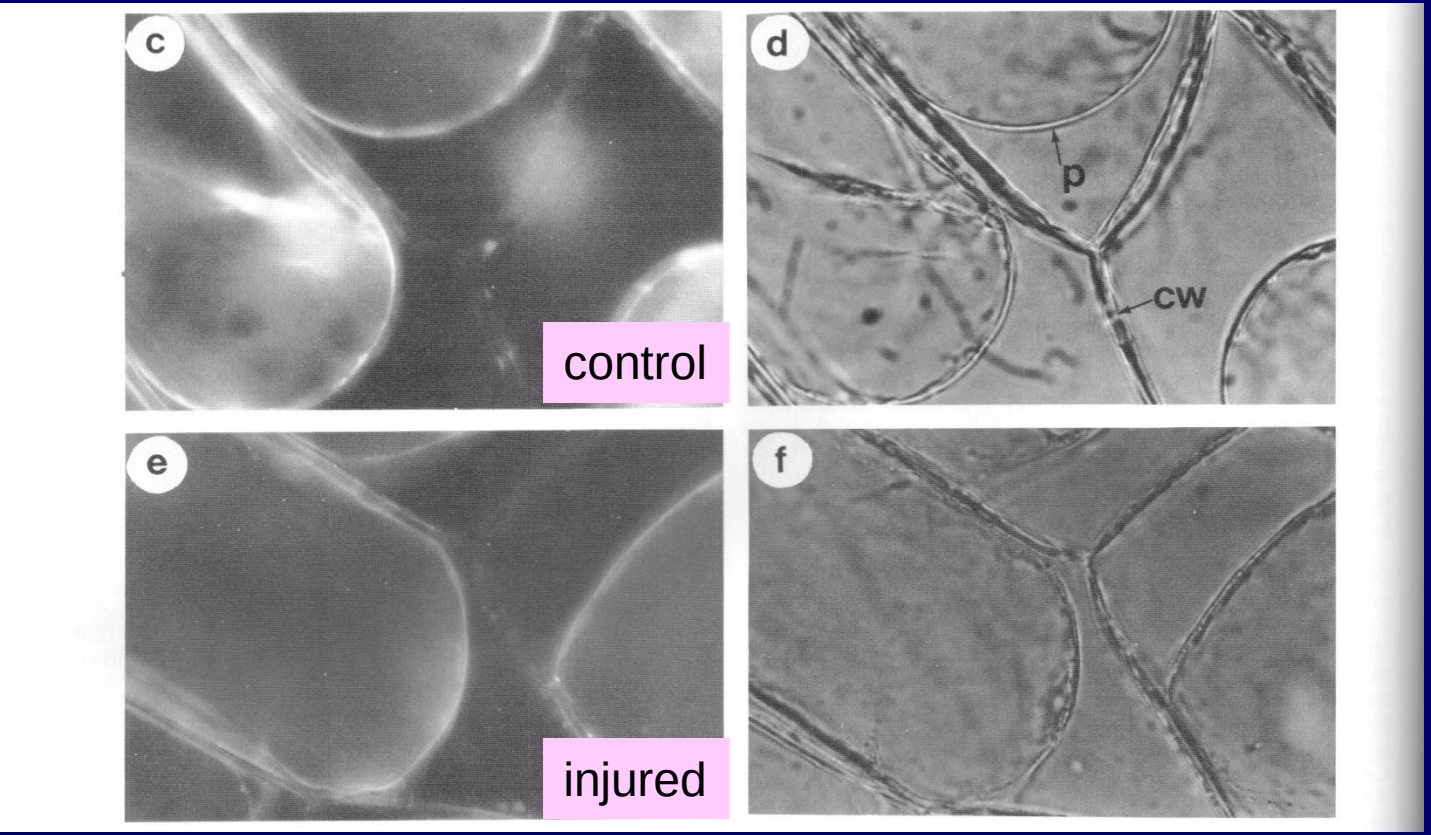
Arora and Palta, 1988.
Plant Physiol. 87:622-628



Arora and Palta, 1988.
Plant Physiol. 87:622-628

Frost injury ⟶ Selective loss of membrane calcium

Membrane CTC Fluorescence (membrane Ca)



Fluorescence view **Light microscope view**

Arora and Palta (1988)
Plant Physiol. 87:622-628.

~ 30% yield increase under heat stress condition

Biotron studies (simulated heat stress)

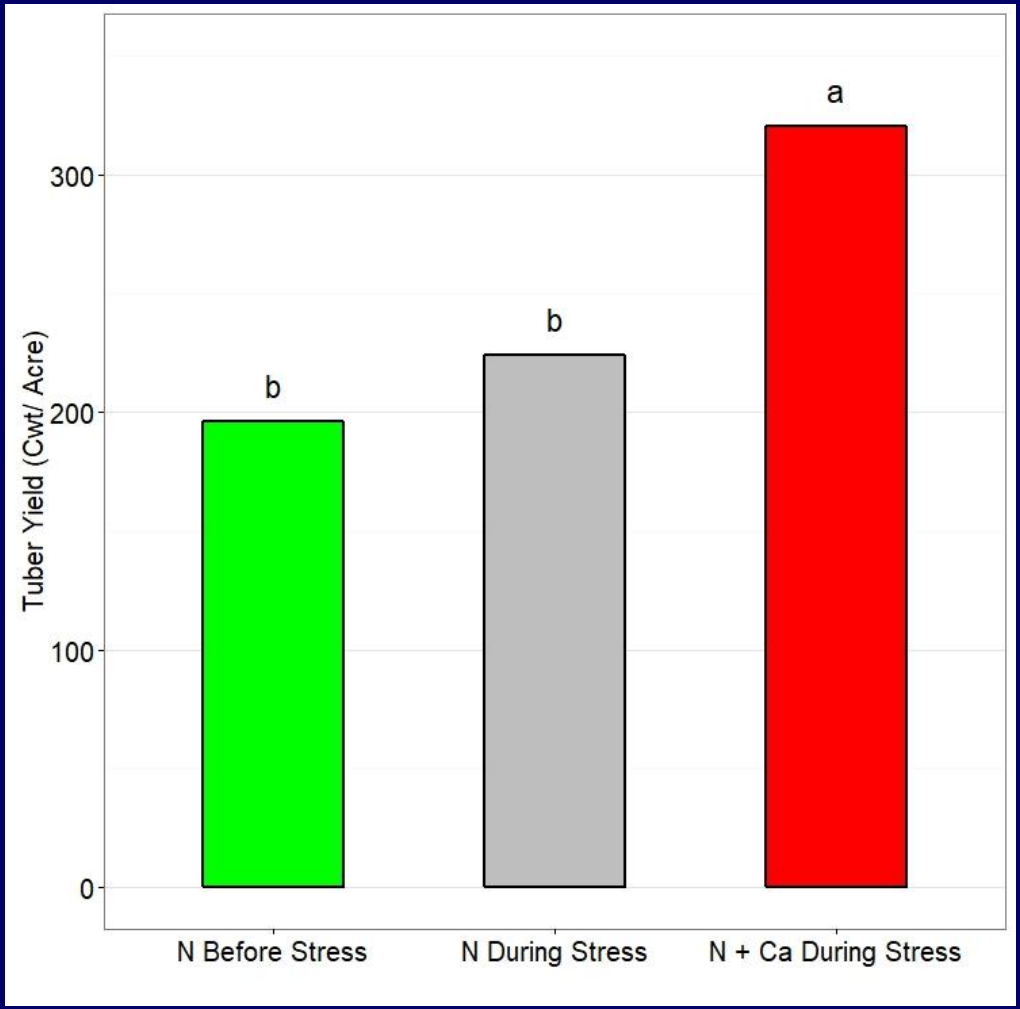
Russet Burbank

5 gallon pots : field soil

1100 lbs/acre exchangeable calcium

Heat stress ~ 2 months after emergence

86 F (day) and 68 F (night) for 4 weeks



Tawfik, Kleinhenz and Palta 1996. Amer. Potato J. 73:261-273.

Conclusions

1. Calcium important for

- Membrane health
- Cell wall strength

2. Calcium acts like a bio-regulator

3. Potatoes are naturally deficient in calcium

4. It is possible to increase tuber calcium by

- Spoonfeeding during bulking
- Soluble calcium

5. Tuber quality is improved by calcium
   - Reduce storage rot
   - Reduce internal defects
   - Improve skin health
   - Improve seed performance
   - Reduce bruising

6. There is possibility to develop better cultivars by breeding for improved tuber calcium

7. Calcium can mitigate impact of environmental stresses

Marion Kratzke
Sandra Vega
Hedy Simpson
Ahmed Tawfik
Rajeev Arora
Matt Kleinhenz
Chris Gunter
Laurie Weiss
SookHee Park
Bjorn Karlsson
Senay Ozgen
Jim Busse
Cinthya Zorilla

John Bamberg
Alfonso DelRio
CIP Colleagues
Rene Gomez
INIA
Jesus Arcos