150 Years of 'Failed' Progress on Bitter Pit

RM Beaudry, Michigan State University

Ross Courtney, Good Fruit Grower Magazine

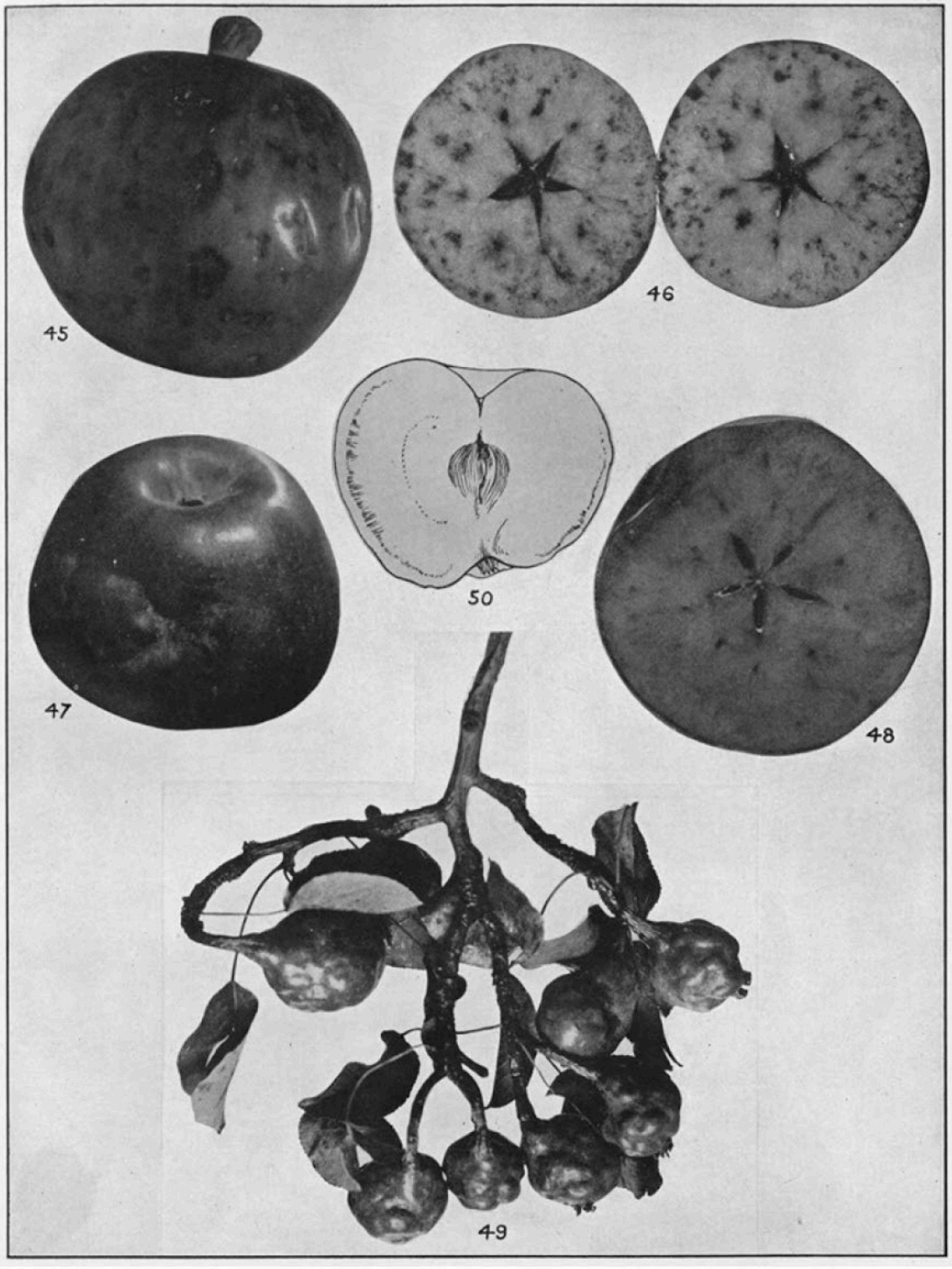

Fig. 7.3 Stigmonosis in Apples. McAlpin's Second Progress Report on Bitter Pit, Plate XXXI (1913) (Courtesy of the Royal Botanic Gardens Library, Melbourne)

Illustrirte

Monatshefte für Obst- u. Weinbau.

Organ des Deutschen Pomologen-Vereins.

Unter der Redaction von

J. G. C. Oberdieck,
Superintendent in Jeinsen,

Dr. Ed. Lucas,
Dir. d. Pom. Instit. in Reutlingen.

Neue Folge V. Jahrgang,

1869.

Mit 18 Tafeln Abbildungen und zahlreichen Holzschnitten.

Portraits: vgl. XII. Personalnachrichten

Ravensburg.

Druck und Verlag von Eugen Ulmer.

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Happy 150th birthday, bitter pit!

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Jäger.

The…**speckling** occurs…in that fresh flesh…, usually around the **outermost circumference of the fruit**, apparently starting from the shell…becomes **dryer** than the fresh fruit meat.

…this phenomenon does not occur in withered fruits, and it seems to me that the means of avoiding or diminishing the occurrence of pitting are found…If my supposition confirms that the airing of the apples prevents or diminishes the fuzziness, then these fruits should be brought into the cellar as late as possible, until a part of their sap has evaporated. …

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Jäger

PRIMER ON BITTER PIT

Symptoms

- Symptoms start internally; damage causes external blemishes and sunken areas
- Pitting occurs at the end of vascular bundles, which terminate near the skin
- Affected areas tend to be more highly colored
- Affected cells die, lose moisture, brown; pits usually 1/16 to 1/8 inch in diameter
- Starch grains present in pitted areas
- Most pits on calyx half of fruit

1/12/2001 5:03pm

PRIMER ON BITTER PIT

Occurrence and Importance

- All regions of world
- More research on this disorder than all others except scald
- Notable varieties include:
  - Baldwin (Baldwin spot)
  - Northern Spy
  - Red Delicious
  - Mutsu (Crispin)
  - Honeycrisp

1/12/2001 5:03pm

Occurrence and Importance

- Fruit predisposed on the tree
- But disorder primarily expressed post-harvest
  - Pitting can occur on tree
  - Healthy fruit on tree can still pit
  - Pitting primarily occurs during ripening
  - Disorder does not spread from fruit-to-fruit
  - Pits may enlarge after storage
  - New pits may form after storage

1/12/2001 5:03pm

PRIMER ON BITTER PIT

Causal Factors

"..all evidence points to its being caused by some maladjustment in the normal water relations of the fruit...anything that accentuates the pulling power of the leaves for water will increase susceptibility to bitter pit"

"Bitter pit is linked with critical levels of calcium in the tissue ... inadequate Ca ... its removal by water stress"

Smock, 1937

PRIMER ON BITTER PIT

Orchard Factors Promoting Bitter Pit

- Heavy N fertilization
- Large fruits (thinning)
- Immature fruit at harvest
- Excessive shading
- Heavy pruning (promotes vegetative growth)
- Dry growing conditions (especially when followed by heavy rainfall or irrigation late in the season
- Low Ca levels in fruit; high Mg/Ca ratio
- Low soil pH

1/12/2001 5:03pm

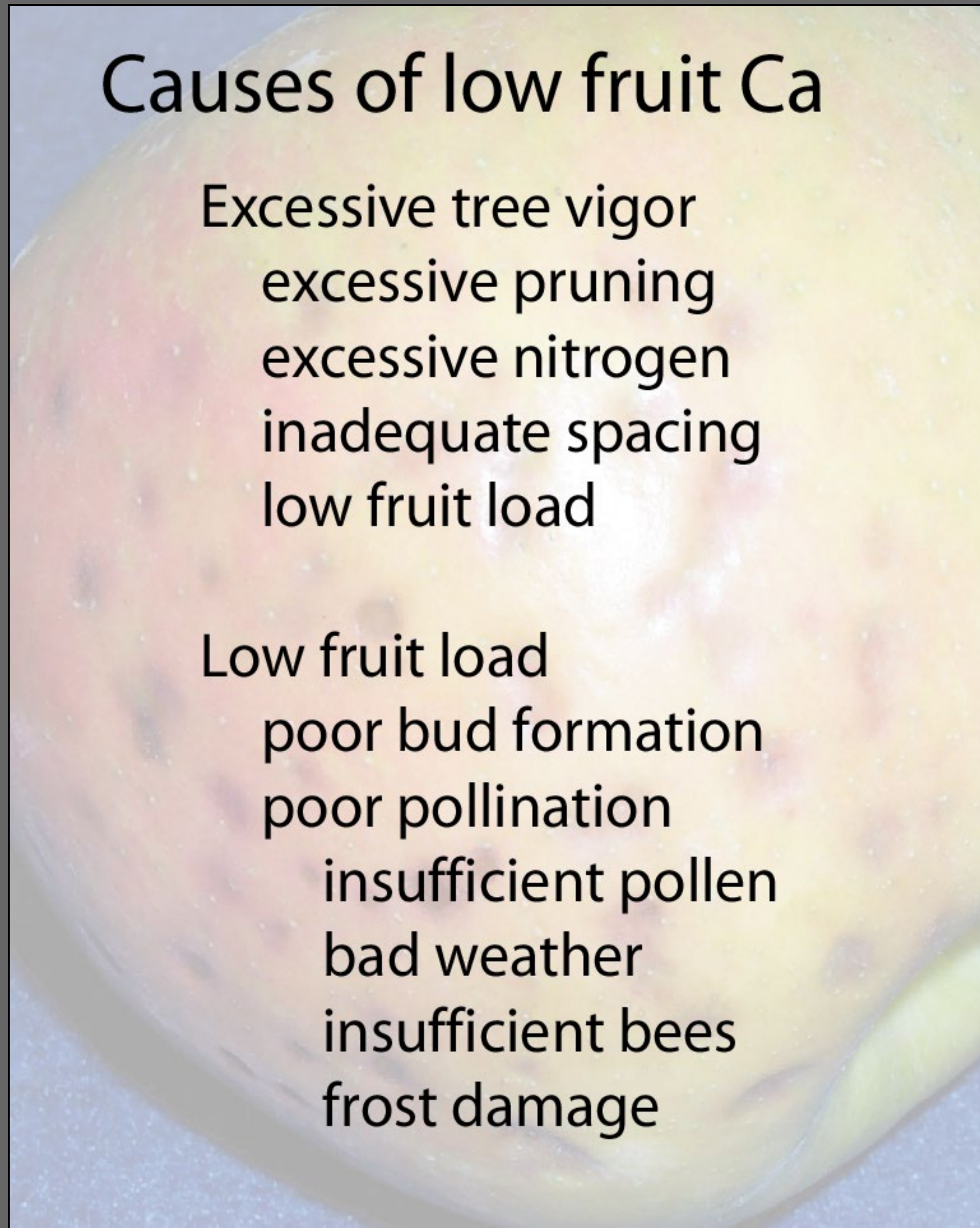
PRIMER ON BITTER PIT

Causes of low fruit Ca

Poor soil conditions
- excessive soil moisture
- deficient soil moisture
- low soil pH

Poor nutrition
- excessive N
- excessive K
- excessive Mg
- deficient Ca
- deficient B

PRIMER ON BITTER PIT



PRIMER ON BITTER PIT

Control of Bitter Pit

Calcium sprays ($CaCl_2$, $CaNO_3$)

- 10 - 50 lb/acre/yr (1.2 - 7.1 lb in each of 7 - 8 sprays)
- Timing - all cover sprays
- Mixing - no problems noted, no stickers/spreaders needed
- Temperature - no problems at these concentrations < 90˚F
- Leaf injury - some following wet, cool springs
- Equipment - $CaCl_2$ corrosive
- Solubor - don't premix with $CaCl_2$

PennState Extension

Rate of Actual Ca Desired in lbs.	10.0

Product	Company	%Ca	lb/gal	Rate of Actual Ca in lbs./A Based on Suggested Label Rates		Enter # Applications	Pounds of Actual Ca Applied Based on # Applications		Number of Applications Needed to Achieve Desired Rate of Ca	
				Rate in lbs./A						
				Low Rate	High Rate	10.0	Low Rate	High Rate	Low Rate	High Rate
Brexil	**Valagro**	15.0%	NA	1	2.5		1.50	3.75	66.7	26.7
lb. actual Ca in lb. material			0.15	0.15	0.375	**lb Ca in single application**				
				Rate in lbs./A						
				Low Rate	High Rate	10.0	Low Rate	High Rate	Low Rate	High Rate
Briner's Choice	**Oxy**	34.0%	NA	2.00	4.00		6.80	13.60	14.7	7.4
lb. actual Ca in lb. material			0.34	0.68	1.36	**lb Ca in single application**				
				Rate in qts./A						
Gallon of product weight in lbs.			11.7	Low Rate	High Rate	10.0	Low Rate	High Rate	Low Rate	High Rate
Calcium 10%	**Loveland**	10.0%		2.00	8.00		13.00	26.00	7.7	3.8
lb. actual Ca in a gallon			1.17	1.30	2.60	**lb Ca in single application**				
				Rate in qts./A						
Gallon of product weight in lbs.			9.20	Low Rate	High Rate		Low Rate	High Rate	Low Rate	High Rate
Calcium 5X	**Stoller**	5.0%		1.00	NL		0.00	NL	83.3	NL
lb. actual Ca in a gallon			0.46	0.12	NL	**lb Ca in single application**				
				Rate in lbs./A						
Gallon of product weight in lbs.			NA	Low Rate	High Rate		Low Rate	High Rate	Low Rate	High Rate
Calcium Chelate	**Miller**	9.5%		0.5	1		0.00	0.00	210.5	105.3

https://extension.psu.edu/orchard-nutrition-calcium-rate-calculator-for-individual-product-comparisons

Apple Nutrition

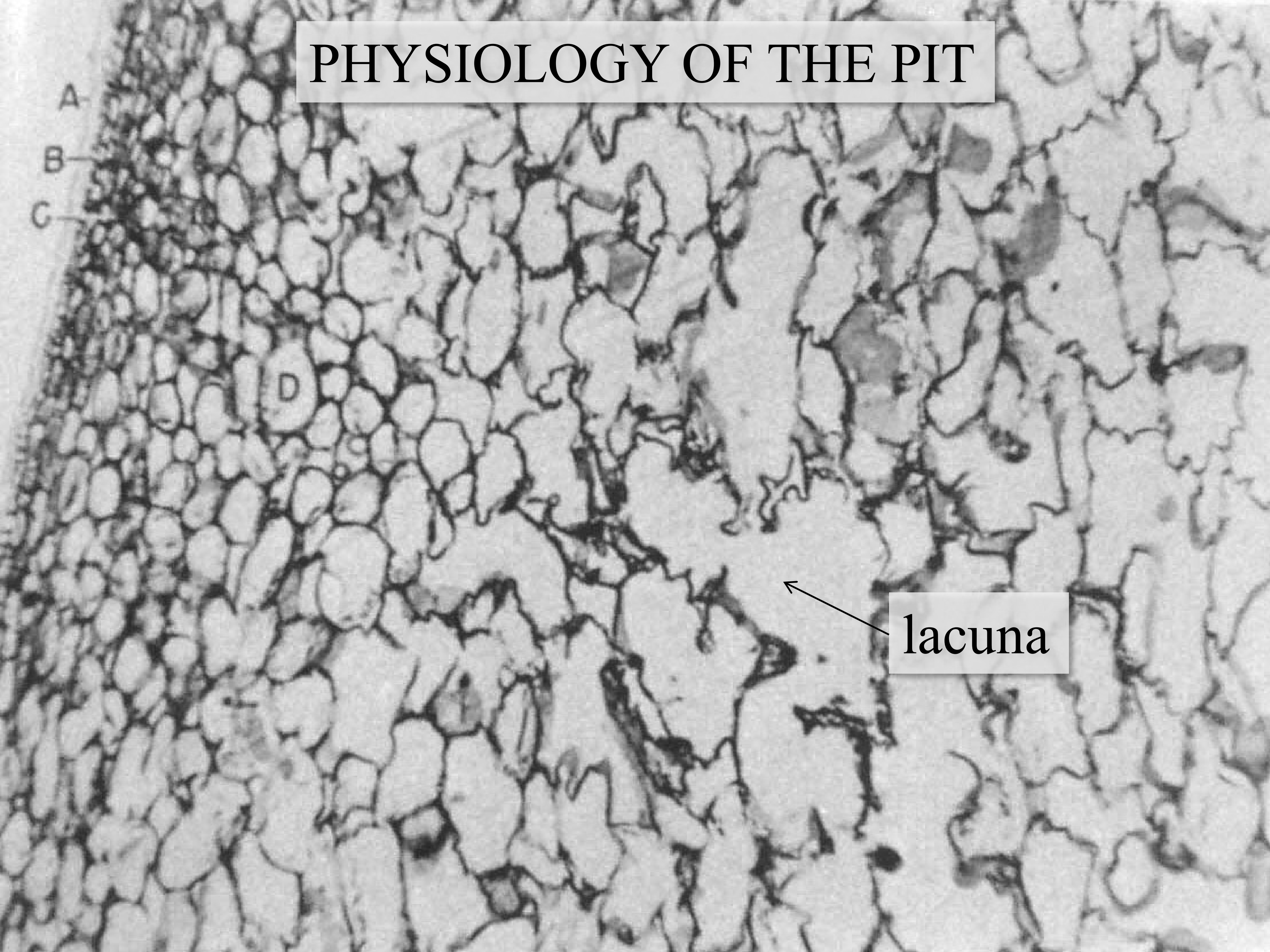
Eric Hanson, Department of Horticulture

Table 3. Optimum and deficient levels of nutrients in apple leaves.

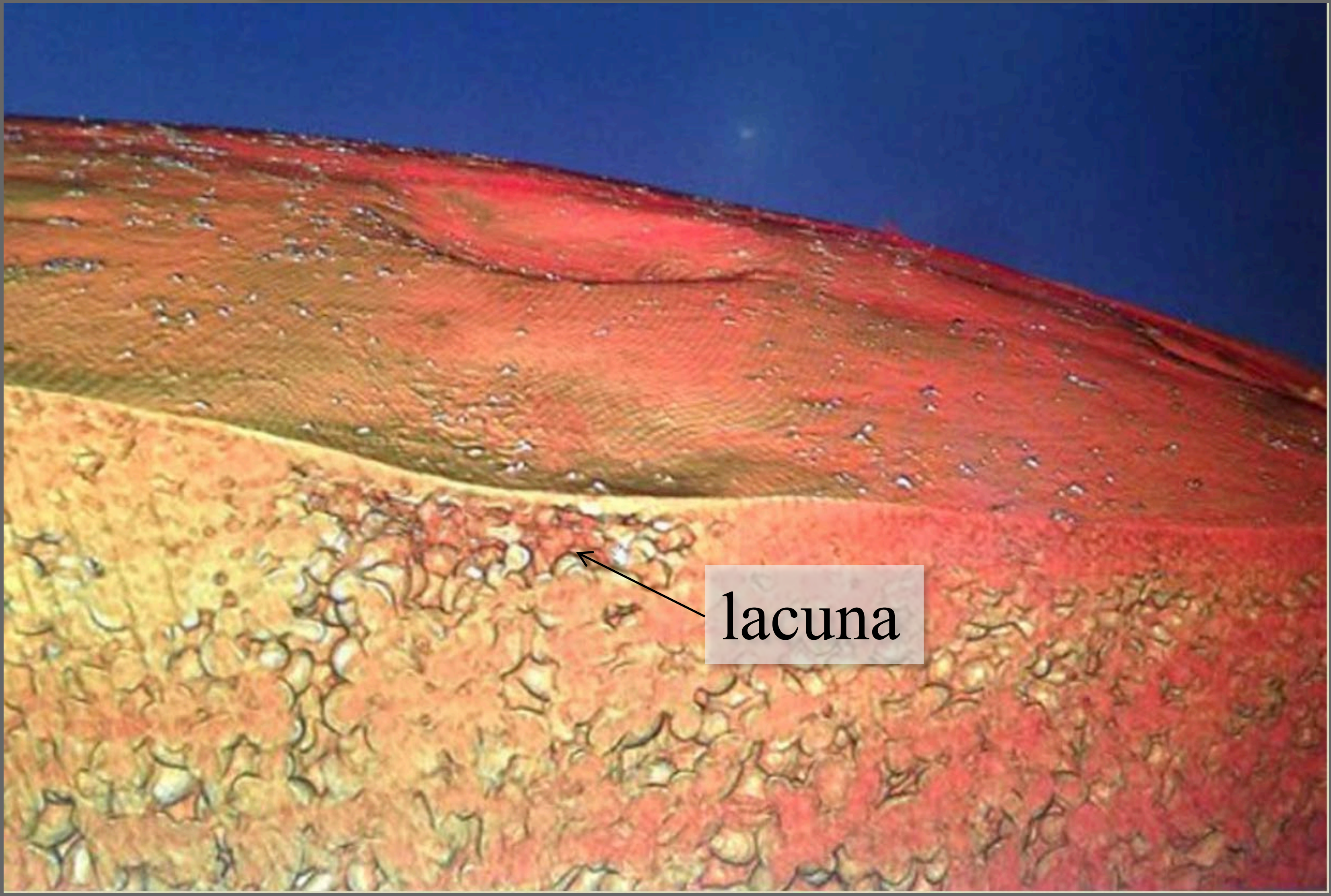
Nutrient	Optimum range	Deficient level
N (%)	2.0-2.6 1.8-2.4[1]	2.0
P (%)	.16-.30	0.11
K (%)	1.3-1.5	1.0
Ca (%)	1.1-1.6	0.5
Mg (%)	.30-.50	0.2
B (ppm)	25-50	25
Cu (ppm)	10-20	4**
Fe (ppm)	150-250	25
Mn (ppm)	50-80	20**
Zn (ppm)	20-40	15**

[1]Optimum range for soft varieties, e.g. Golden Delicious and Macintosh.
**indicates deficient levels is not well defined

PHYSIOLOGY OF THE PIT



PHYSIOLOGY OF THE PIT



Lee Kalcits, Good Fruit Grower Magazine

CHEMICAL INVESTIGATIONS ON BITTER PIT OF APPLES

III. CHEMICAL COMPOSITION OF AFFECTED AND NEIGHBOURING HEALTHY TISSUES

By H. O. ASKEW, E. T. CHITTENDEN, R. J. MONK, and JOYCE WATSON, Cawthron Institute, Nelson

(*Received for publication, 23 November 1959*)

TABLE 2. PERCENTAGES OF MINERAL AND NITROGEN ON D.M. BASIS OF AFFECTED AND HEALTHY TISSUE FROM FRUITS FROM MOUTERE, 1959

Treatment	Status	Bitter Pit %	Total Ash %	Ca %	Mg %	P %	K %	Na %	N %
Cont. (1–4)	Pitted	27	2.69	0.038	0.14	0.086	0.71	0.009	0.57
Cont. (1–4)	Healthy	-	1.78	0.012	0.029	0.040	0.56	0.008	0.46
Cont. (1–4)	Original	- -	1.53	0.026	0.029	0.050	0.59	0.011	0.43

Total ash content was significantly positively related to increasing incidence of bitter pit. High values of the ratios Mg/Ca, K/Mg, K/Ca, and K/N accompanied high incidence of bitter pit in the fruit.

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"-in the pitted tissue the ratio Mg/Ca (~4) is twice as high as in the nominally healthy (surrounding) tissue"

"Even more striking are the differences in the values of the K/Mg ratios; here the pitted tissue shows the relatively low values of a little over 6, while the [healthy] tissues have values of [approximately 22]"

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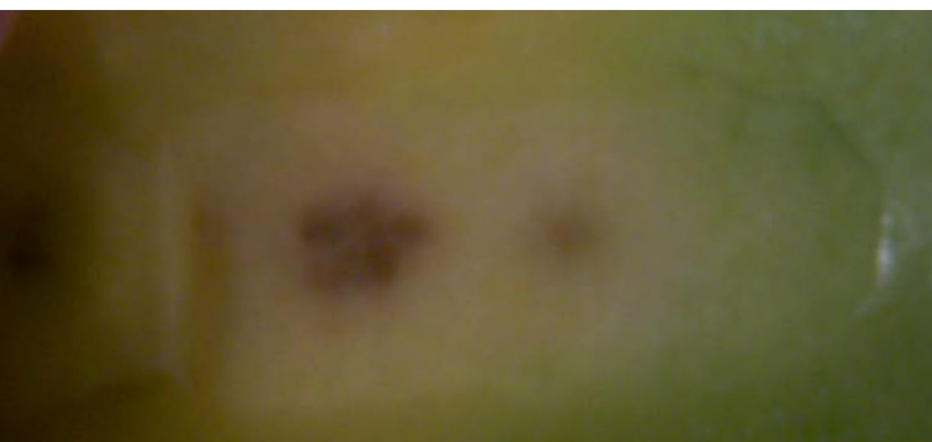
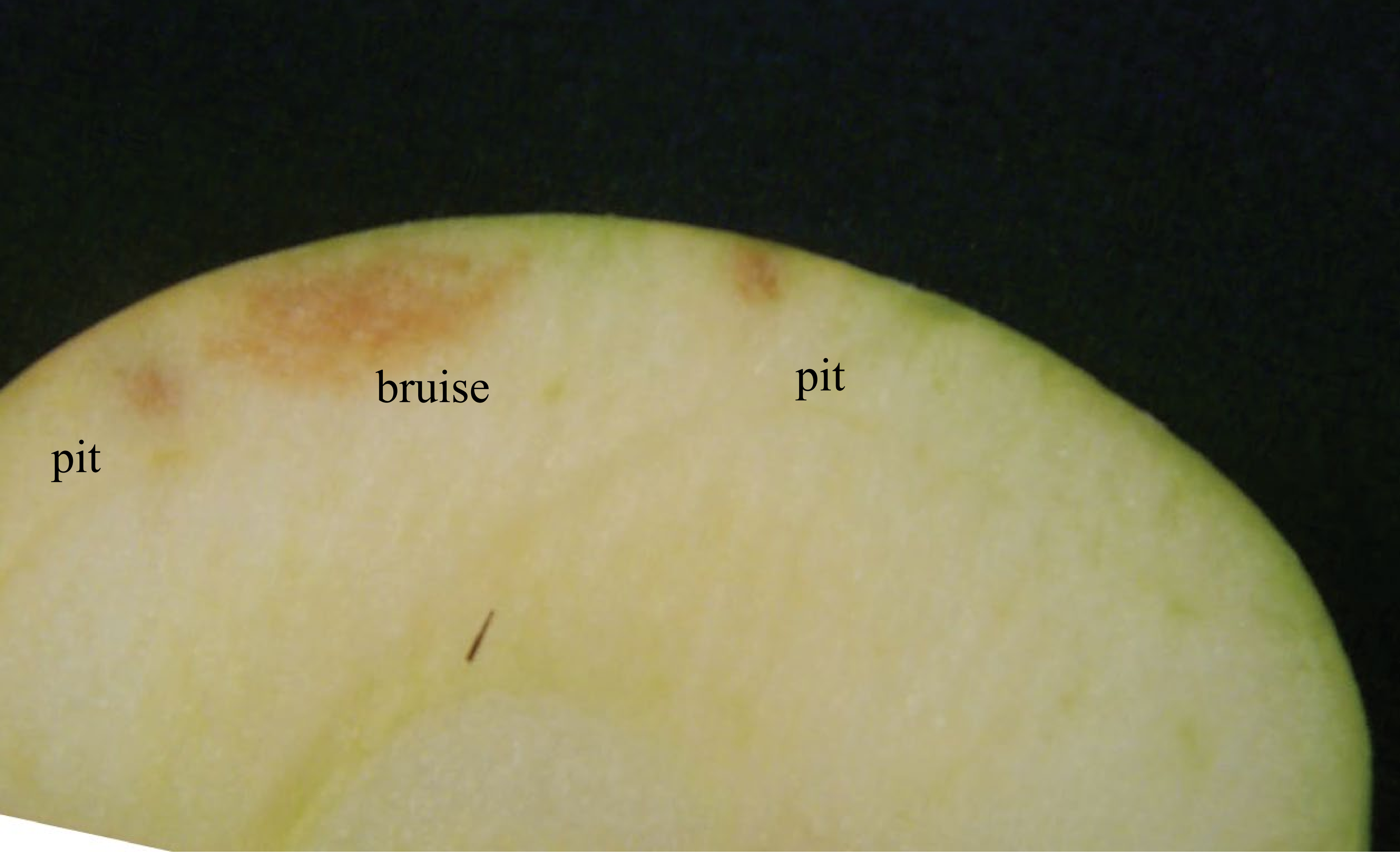
"Tissue from the affected areas was very low in sucrose, but was well supplied with glucose and fructose."

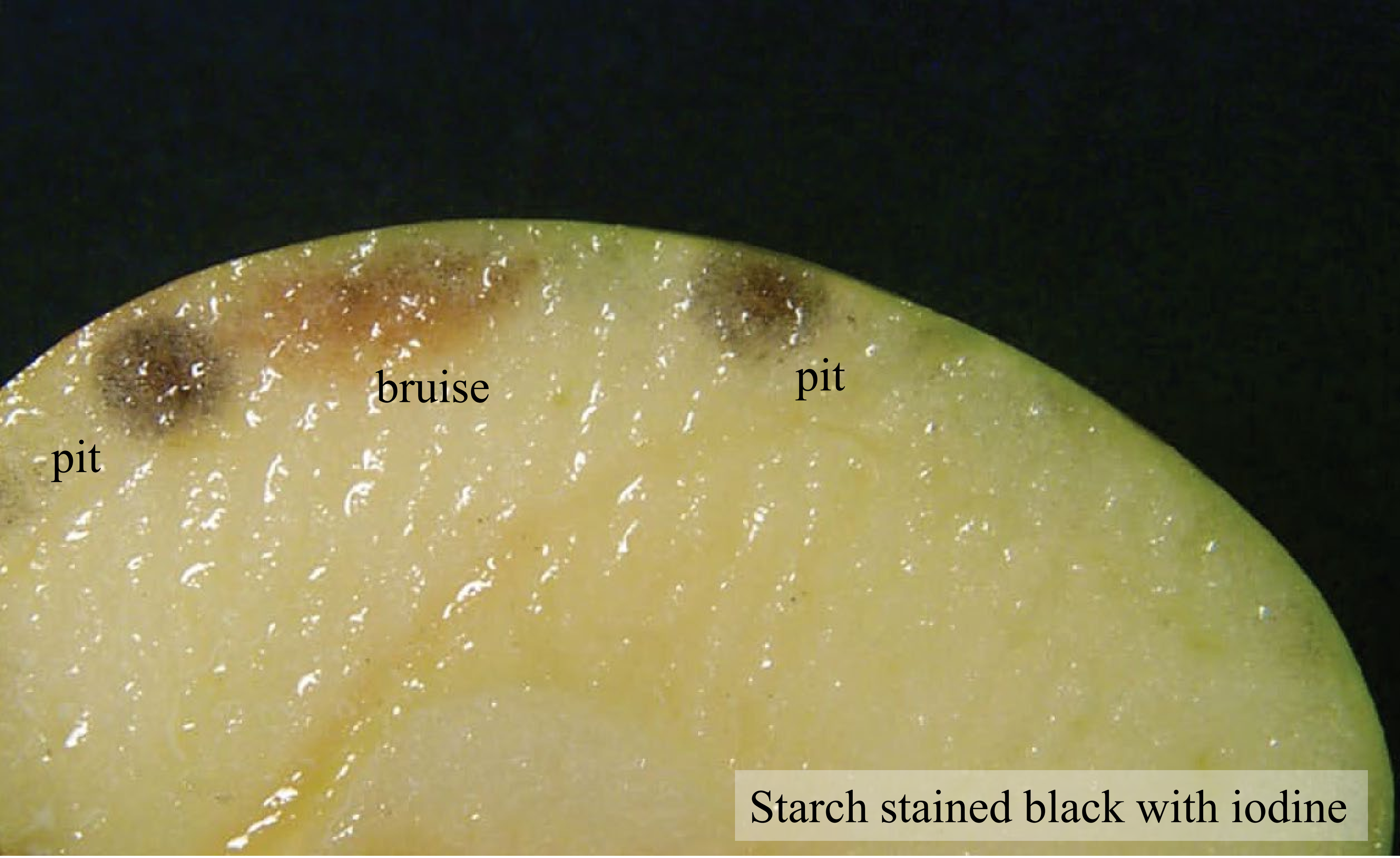
"There are - very great differences in the starch contents of the two types of tissue"



Starch stained black with iodine



Starch appears to be concentrated in damaged and apparently healthy tissue



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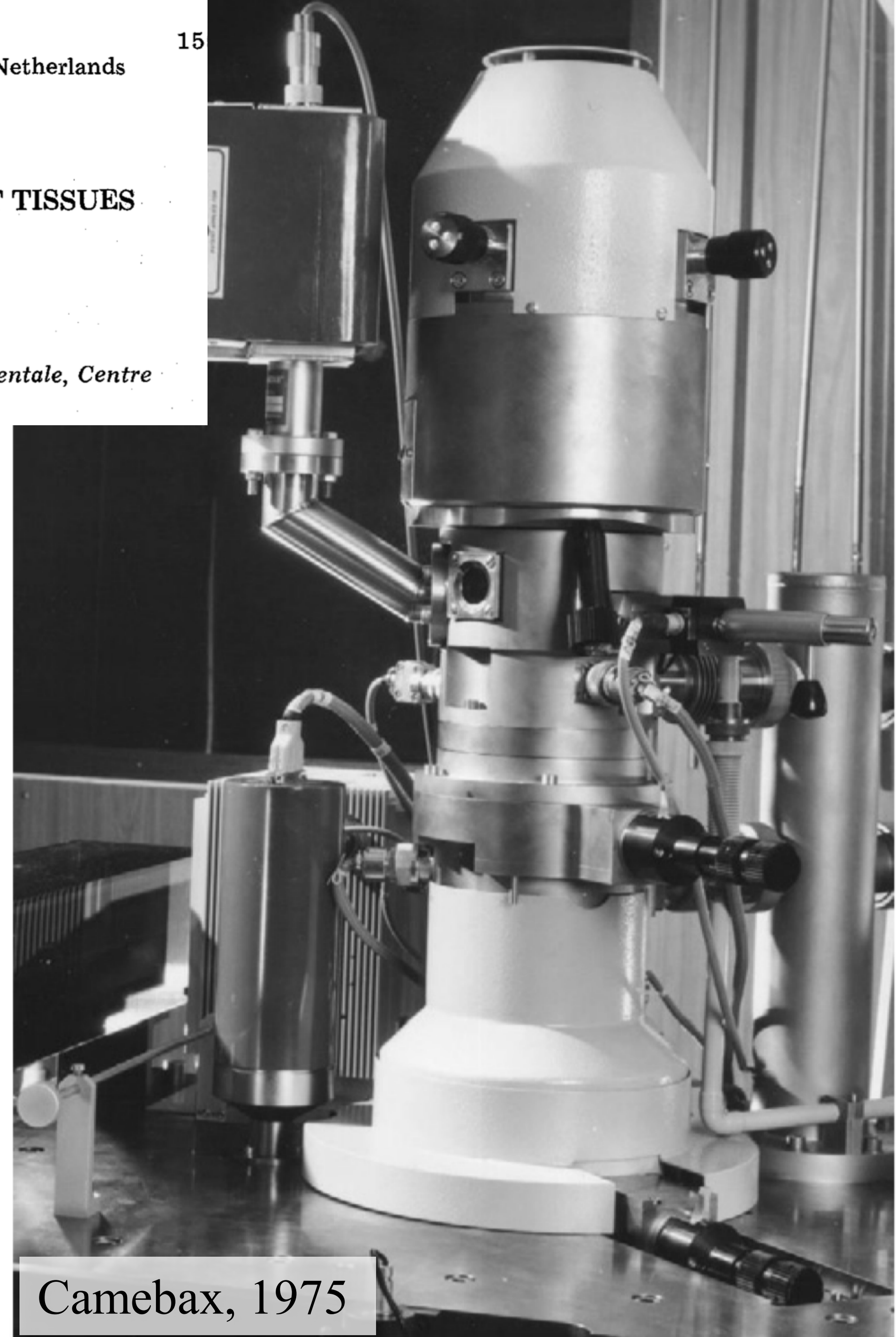
Scientia Horticulturae, 15(1981) 155—163 15
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

ELECTRON-MICROPROBE ANALYSIS OF APPLE FRUIT TISSUES AFFECTED WITH BITTER PIT

A.R. CHAMEL and J.P. BOSSY

Laboratoire de Biologie Végétale, Département de Recherche Fondamentale, Centre d'Etudes Nucléaires, 85 X 38041 Grenoble, Cedex (France)

“sample is bombarded with an electron beam, emitting x-rays at wavelengths characteristic to the elements being analyzed”



Camebax, 1975

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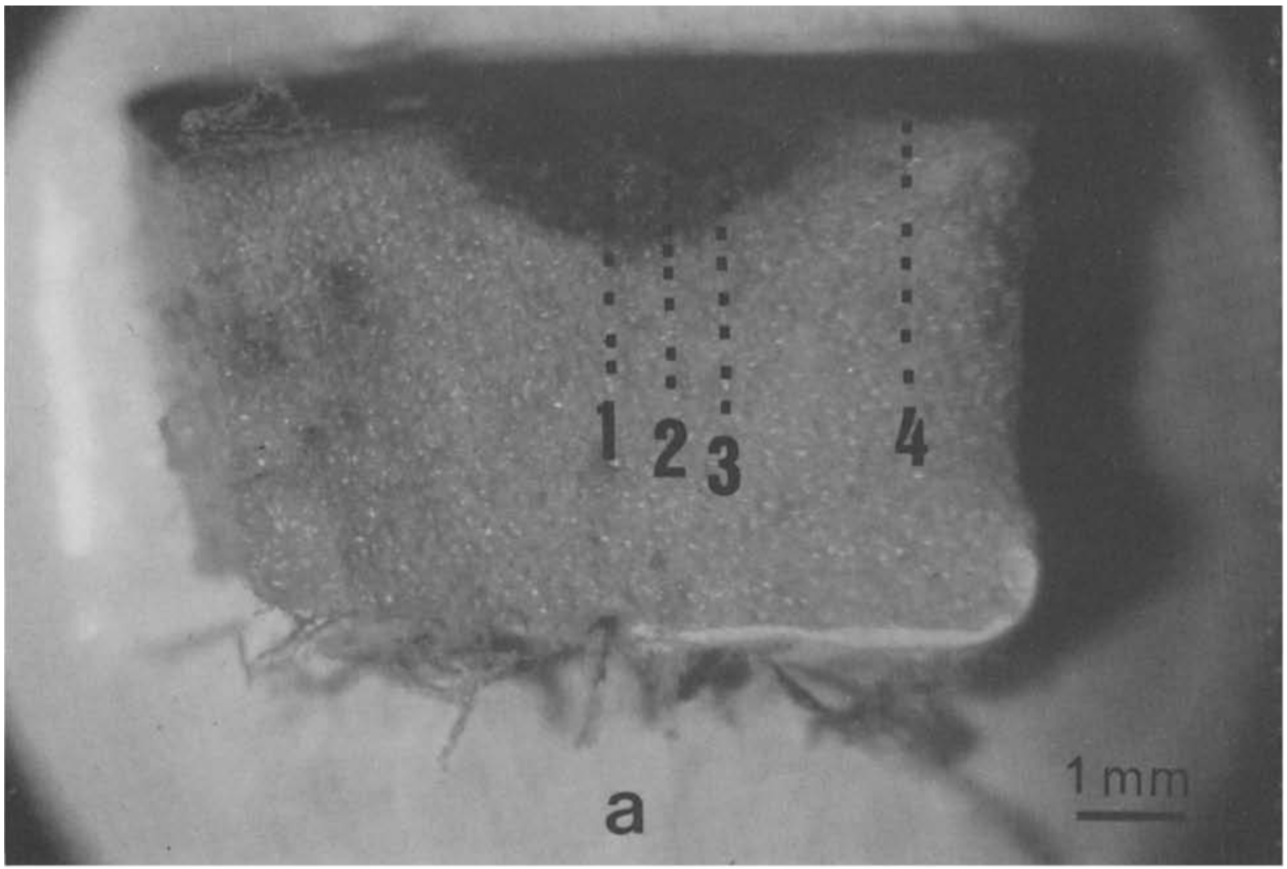

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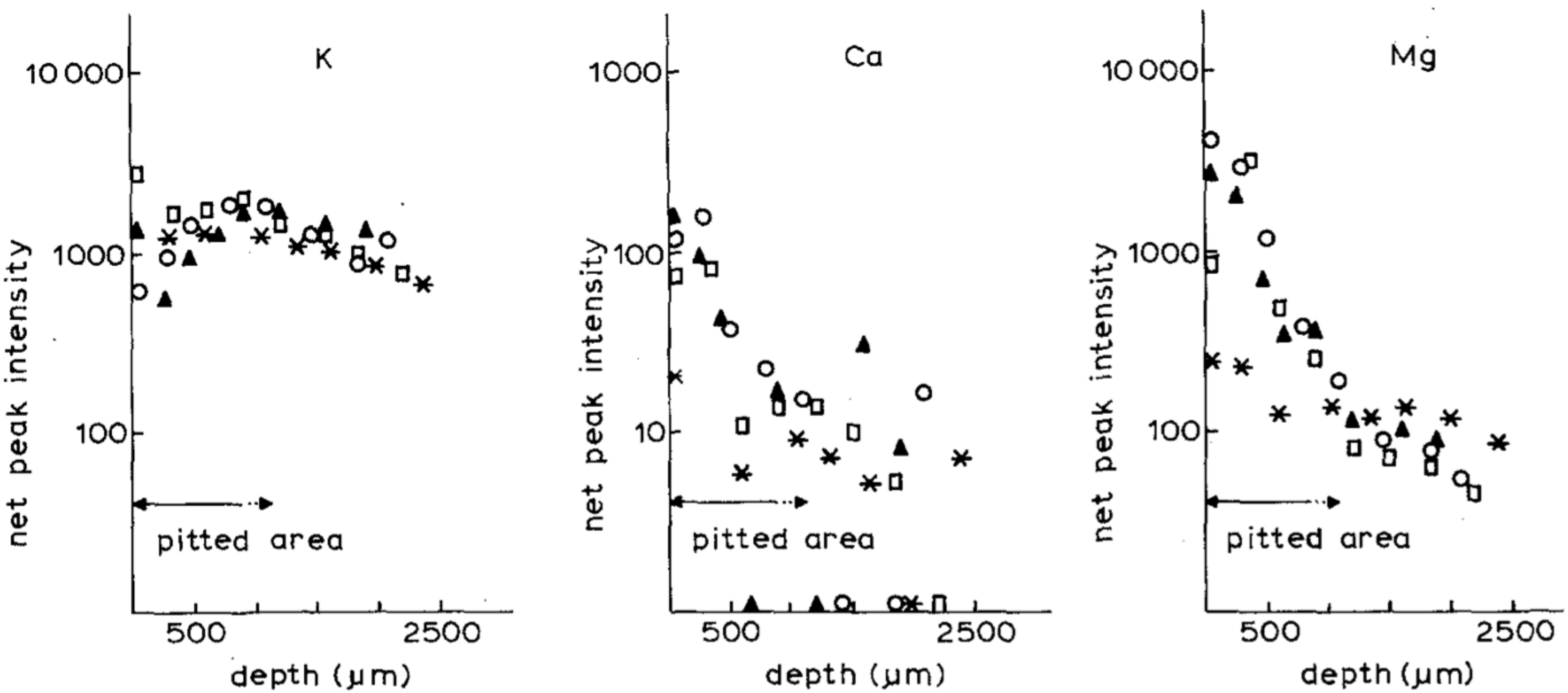

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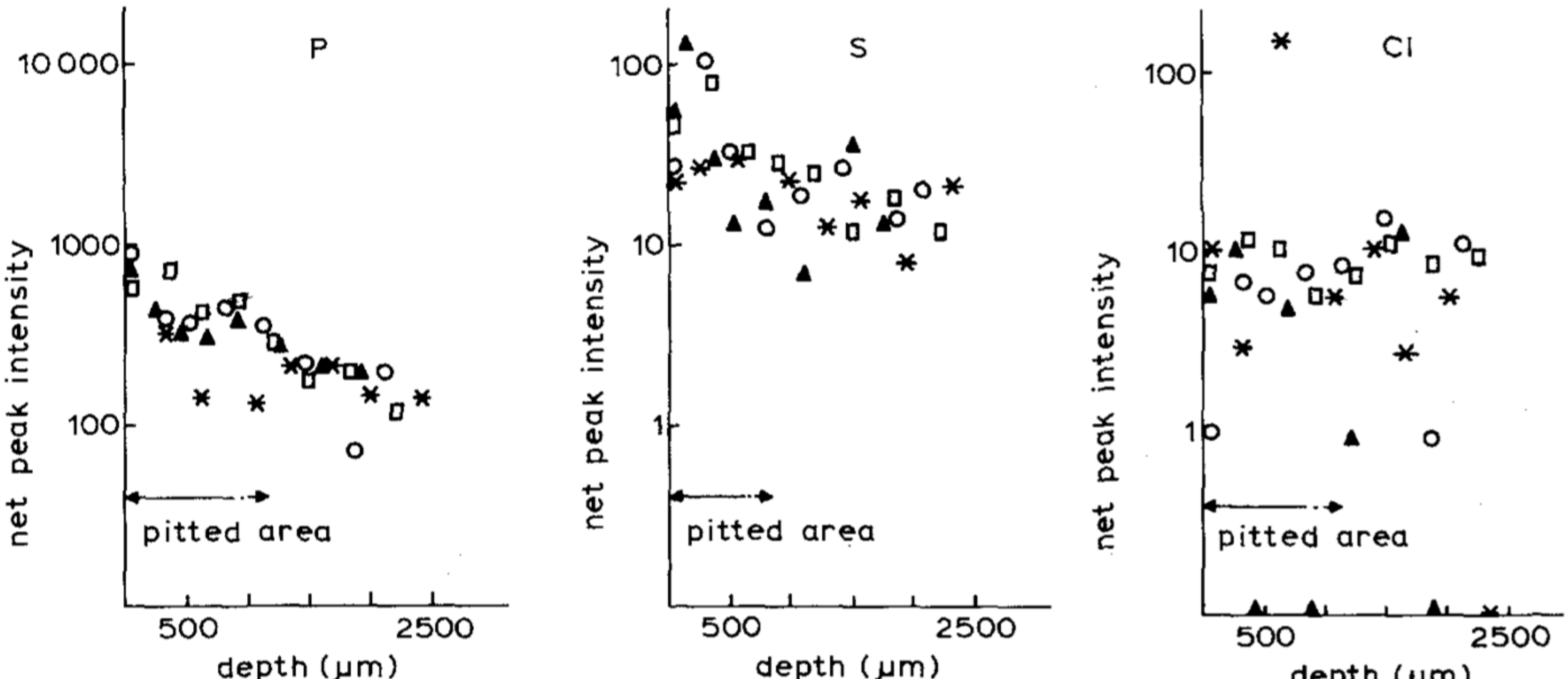

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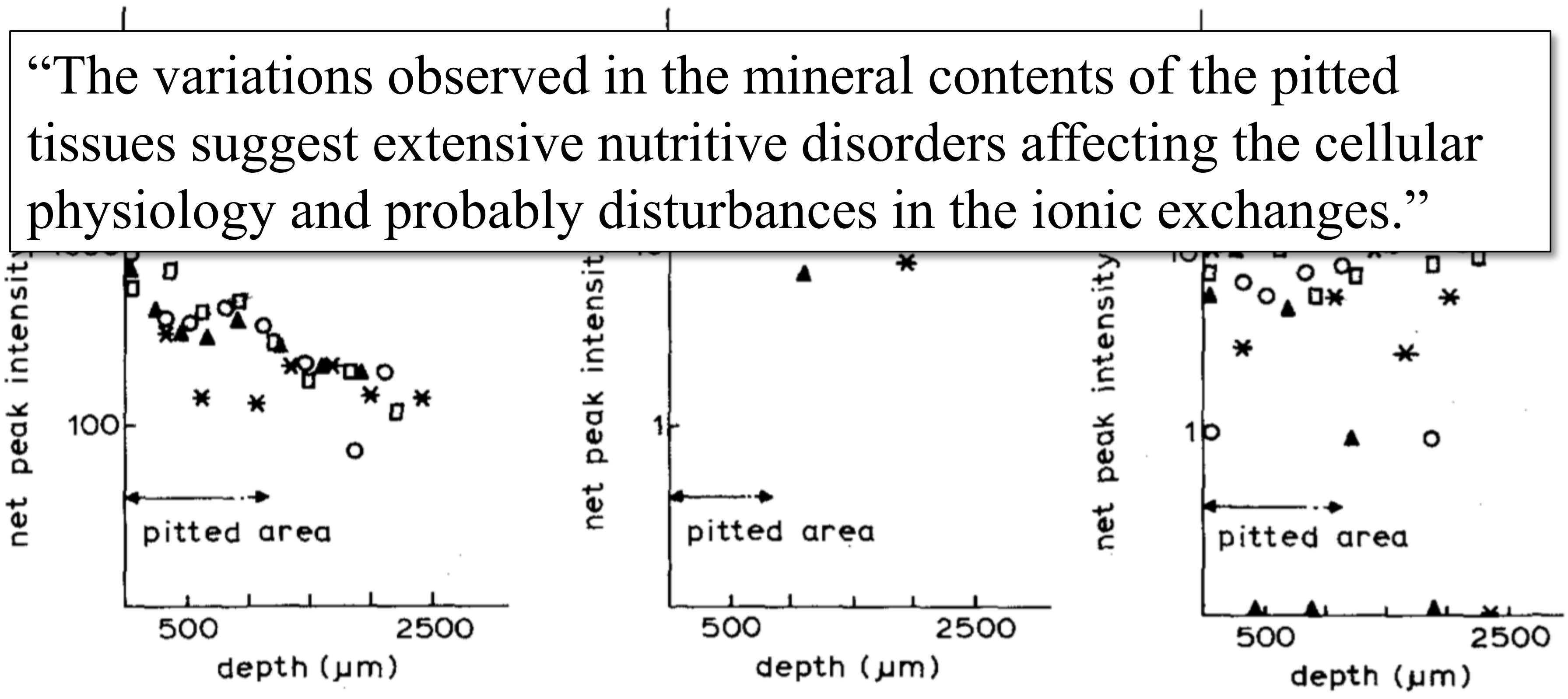
“The variations observed in the mineral contents of the pitted tissues suggest extensive nutritive disorders affecting the cellular physiology and probably disturbances in the ionic exchanges.”

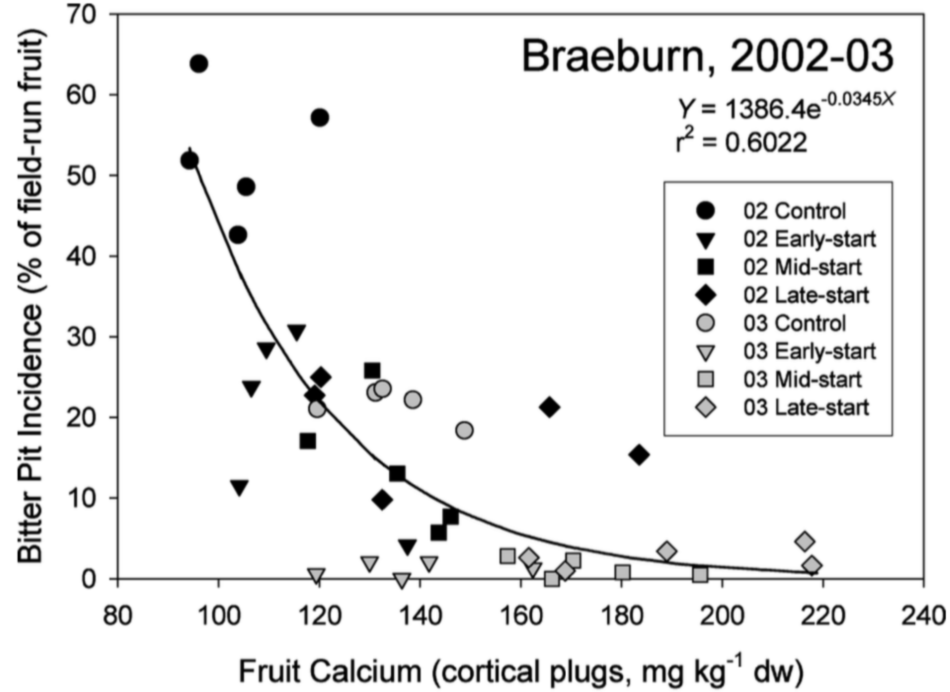


Start-Timing for Calcium Chloride Spray Programs Influences Fruit Calcium and Bitter Pit in 'Braeburn' and 'Honeycrisp' Apples

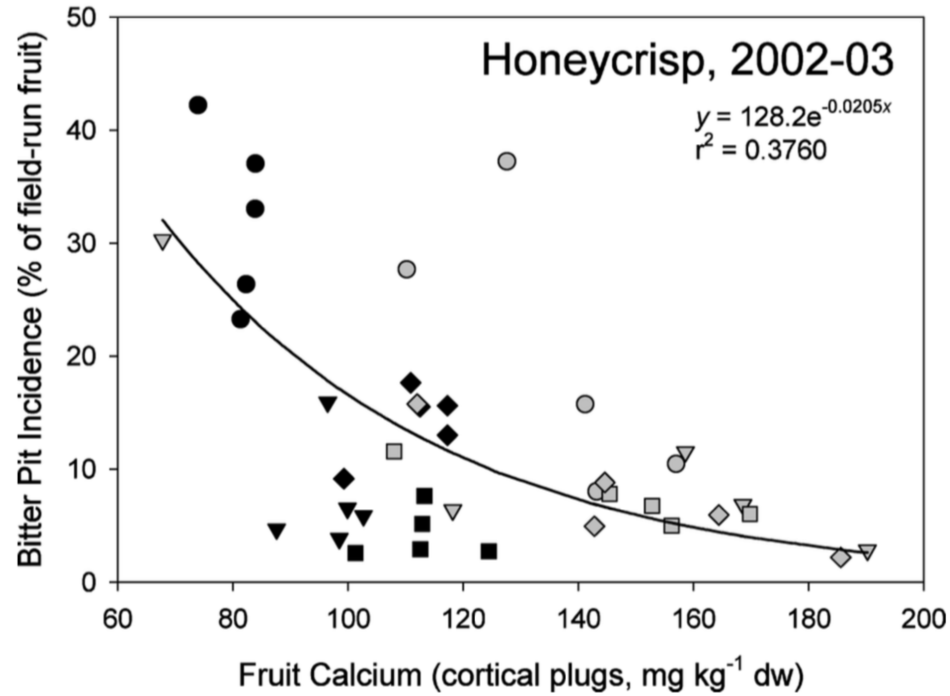
Frank J. Peryea , Gerry H. Neilsen & Dana Faubion

To cite this article: Frank J. Peryea , Gerry H. Neilsen & Dana Faubion (2007) Start-Timing for Calcium Chloride Spray Programs Influences Fruit Calcium and Bitter Pit in 'Braeburn' and 'Honeycrisp' Apples, Journal of Plant Nutrition, 30:8, 1213-1227, DOI: 10.1080/01904160701555077

To link to this article: http://dx.doi.org/10.1080/01904160701555077



Relationship between bitter pit incidence and fruit cortical plug Ca concentration of apples harvested from unsprayed apple trees and from trees that received 6 bi-weekly sprays of 5 g $CaCl_2$ L^{-1} starting mid-May (early-start), mid-June (mid-start), or mid-July (late-start) 2002 and 2003.



Start-Timing for Calcium Chloride Spray Programs Influences Fruit Calcium and Bitter Pit in 'Braeburn' and 'Honeycrisp' Apples

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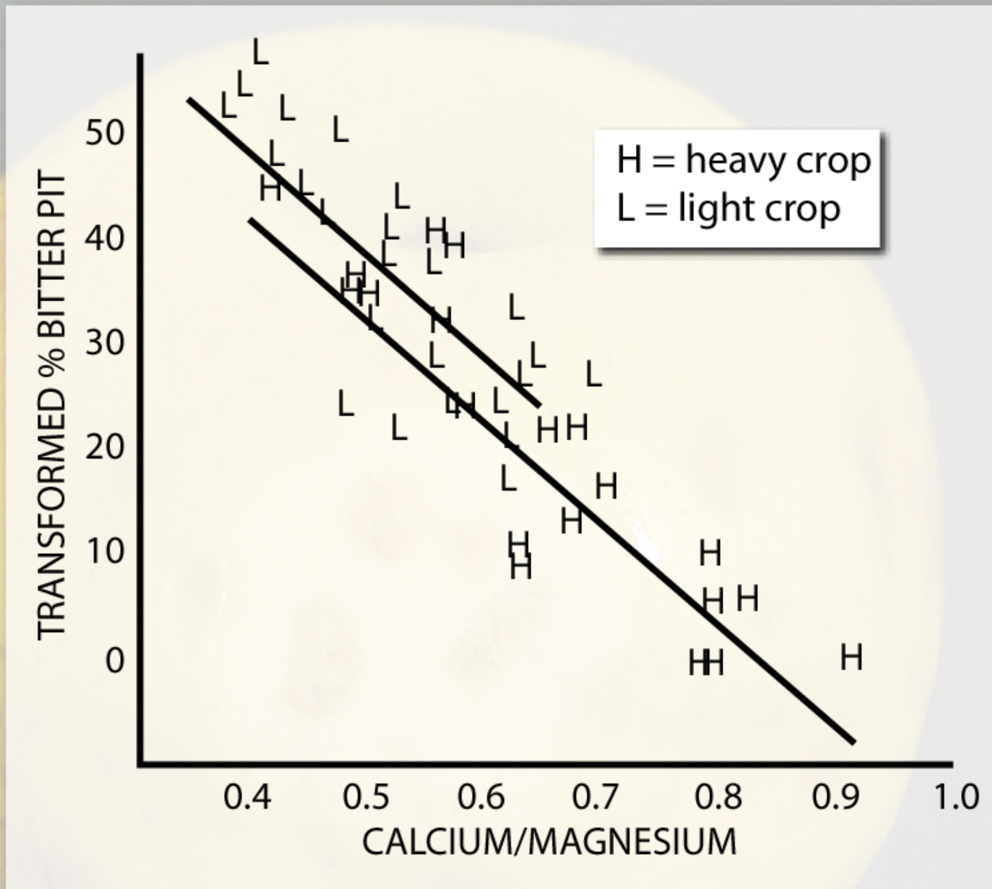
To link to this article: http://dx.doi.org/10.1080/01904160701555077

Percent bitter pit for fruit harvested from unsprayed apple trees (Control) and from trees that received 6 bi-weekly sprays of 5 g $CaCl_2$ L^{-1} starting mid-May, mid-June, or mid-July 2002 and 2003

	Control	May start	June start	July start
Braeburn, 2002	52.8	19.8	13.9	18.8
Braeburn, 2003	21.6	1.2	1.3	2.6
Honeycrisp, 2002	32.4	7.4	4.2	14.2
Honeycrisp, 2003	19.8	6.9	7.4	7.5

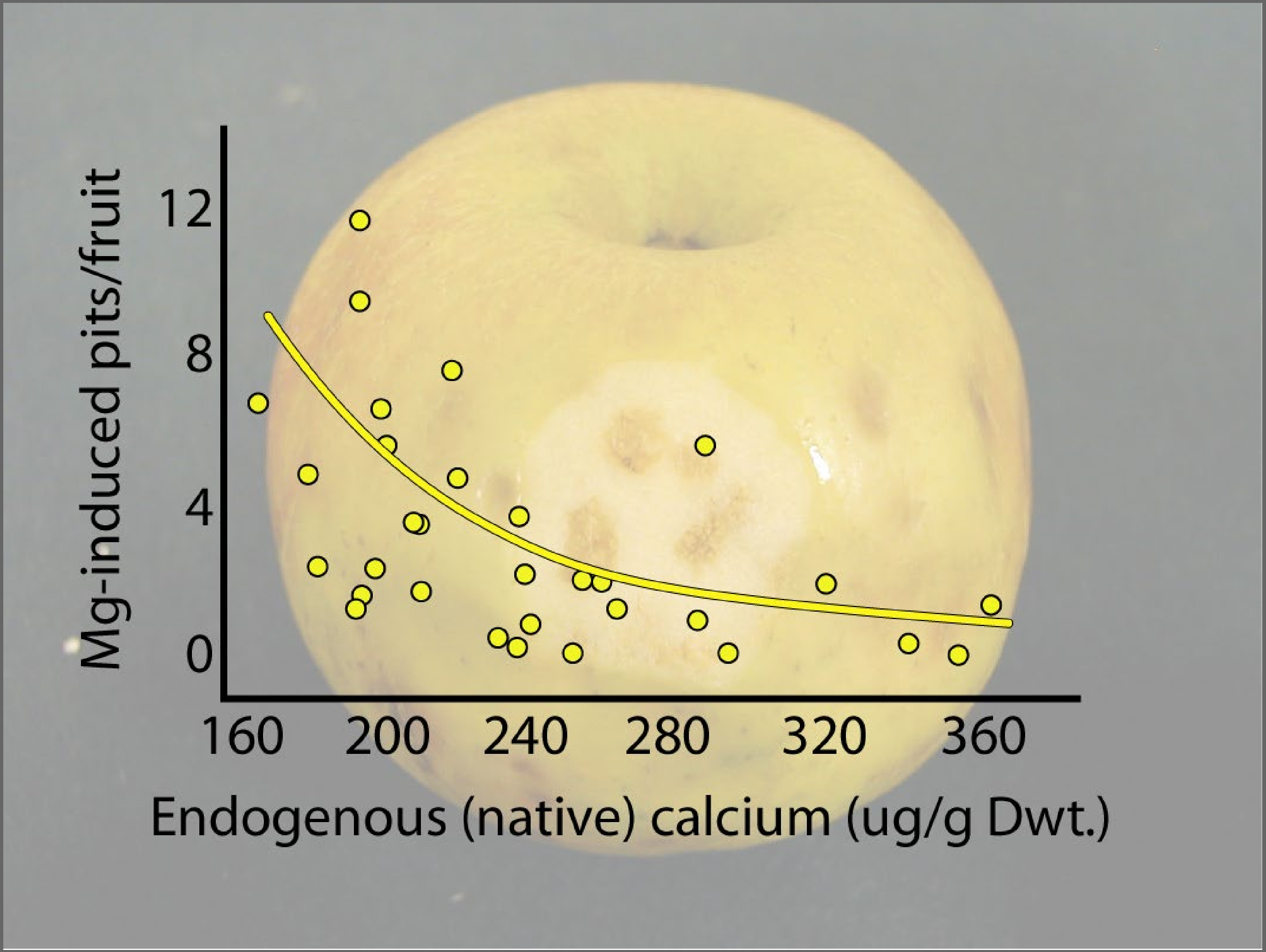


Bitter pit incidence is related to the ratio of calcium to magnesium

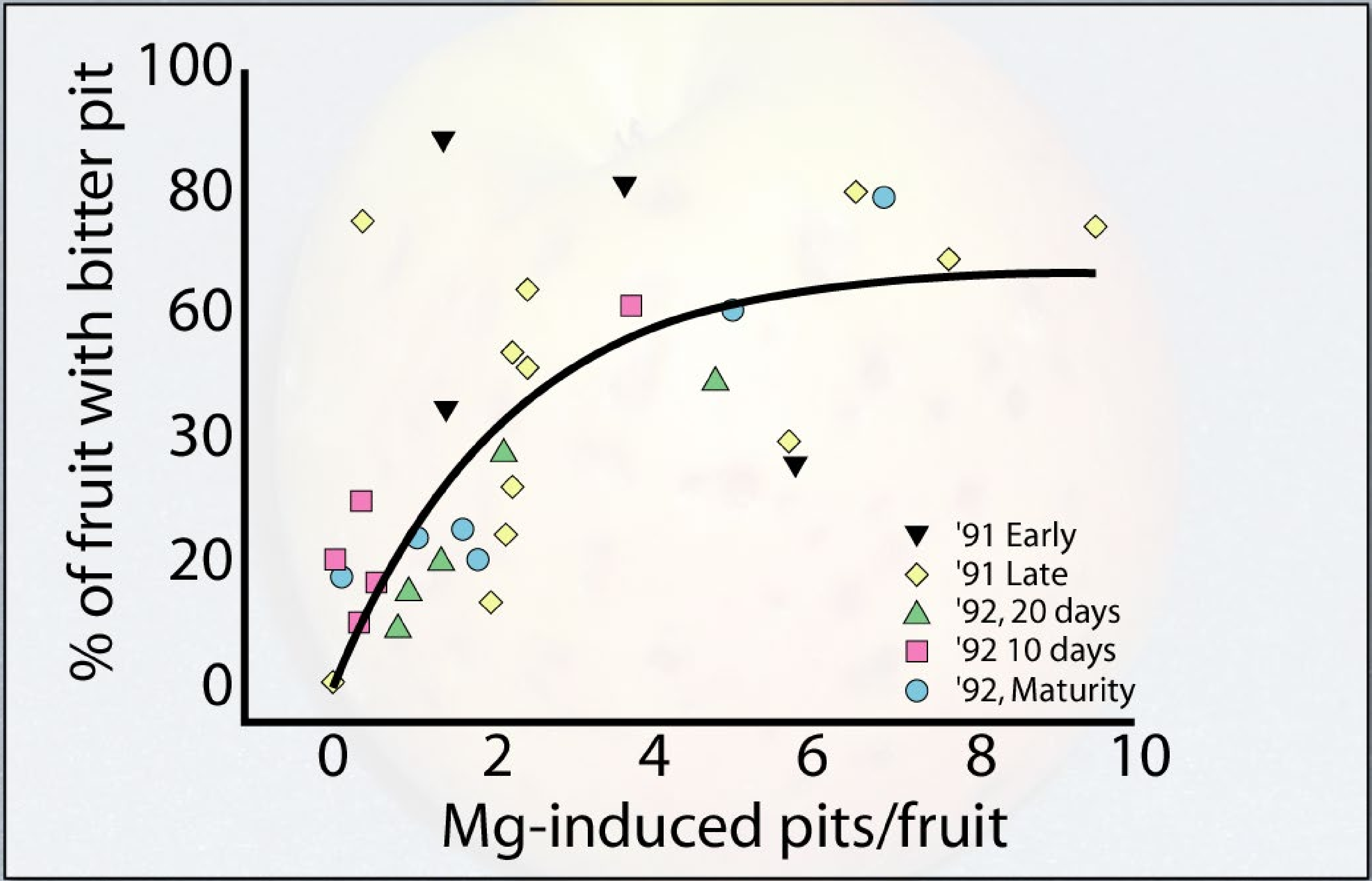
From Ferguson and Watkins, 1992

Magnesium acts in a manner opposite to that of calcium.

Magnesium infiltration can be used to measure fruit susceptibility to bitter pit



Burmeister and Dilley, 1993

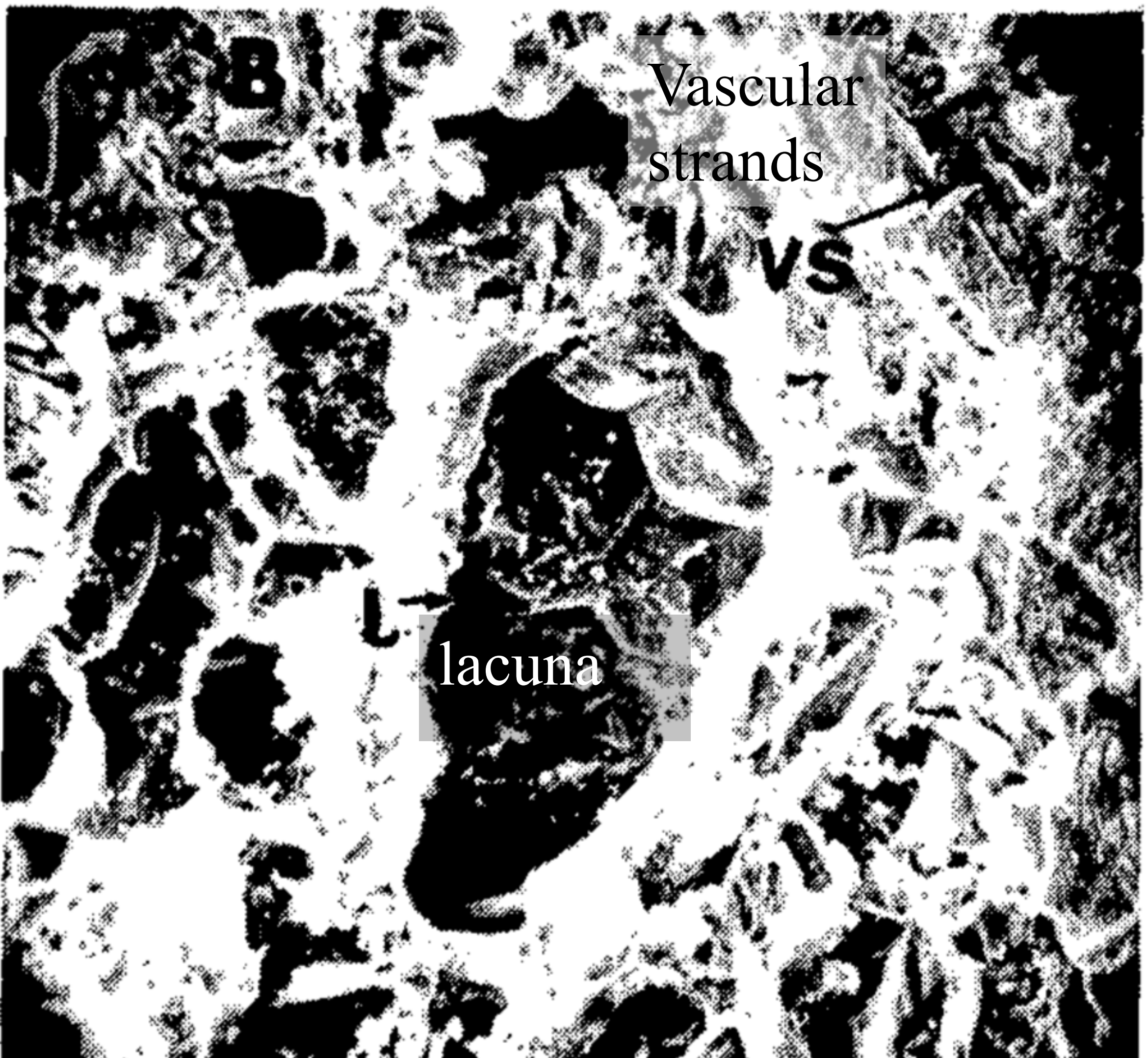


from Burmeister and Dilley, 1993

SCANNING ELECTRON MICROSCOPY AND ELECTRON MICROPROBE STUDIES OF BITTER PIT IN APPLES

ROY K. SIMONS
MEL C. CHU
University of Illinois, USA

1980



"Cell wall thickening and cell collapse evident in the basin area of fruit at 6 weeks post anthesis – a slight reddish brown discoloration was evident in the surface of the fruit – tissue degeneration in the <u>edge of the vascular strands</u> had produced a large lacuna."

Six weeks after anthesis

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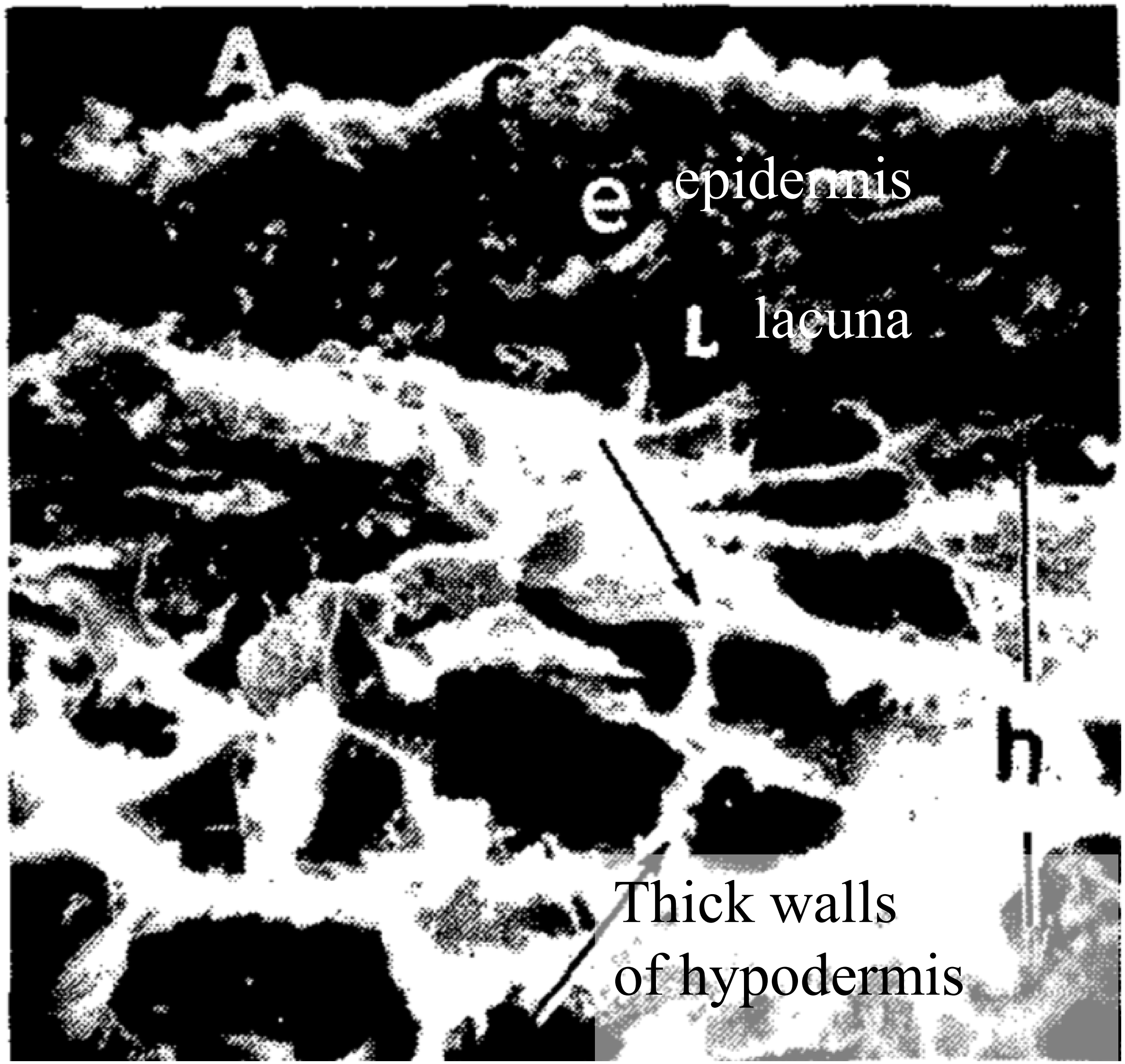

"The cuticle and epidermis were separated from the hypodermis creating a lacuna. The lacuna was contiguous to an area of the hypodermis that consisted of dividing cells adjacent to a zone of tissue containing cells with extremely thick walls."

Six weeks after anthesis

SCANNING ELECTRON MICROSCOPY AND ELECTRON MICROPROBE STUDIES OF BITTER PIT IN APPLES

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1980

"Groups of dividing cells were enclosed in a mother cell wall and, as they developed, collapse and breakdown were noted. Competition from normal cells contiguous to the newly formed cells may contribute to …breakdown of [the newly formed cells]"

Postharvest Biology and Technology 57 (2010) 6–13

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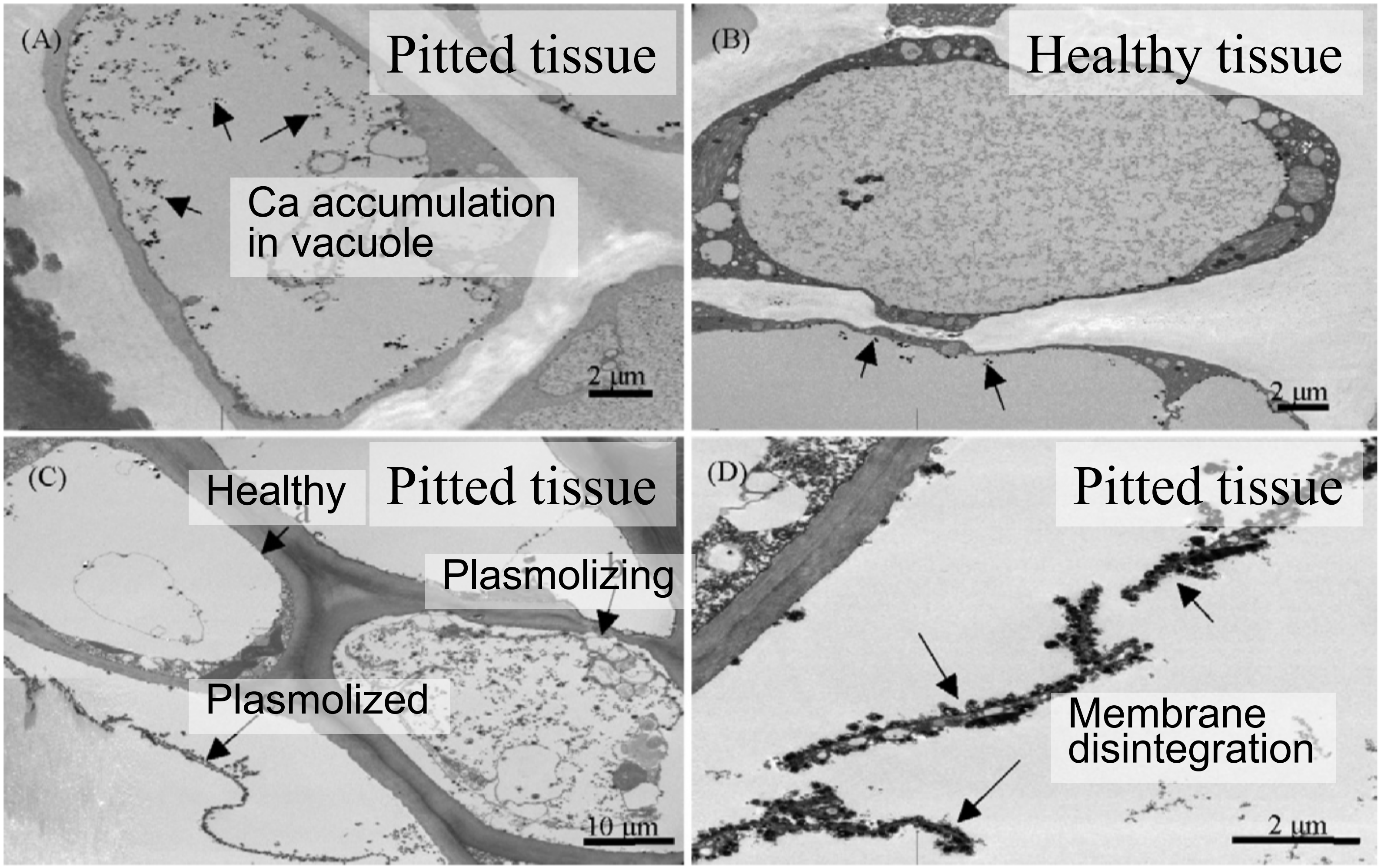
Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Cellular approach to understand bitter pit development in apple fruit

Sergio T. de Freitas[a], Cassandro V.T. do Amarante[b], John M. Labavitch[a], Elizabeth J. Mitcham[a,*]

[a] Department of Plant Sciences, University of California, Davis, CA 95616, USA
[b] Department of Agronomy, University of Santa Catarina State, Lages, SC 88520000, Brazil



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Cellular approach to understand bitter pit development in apple fruit

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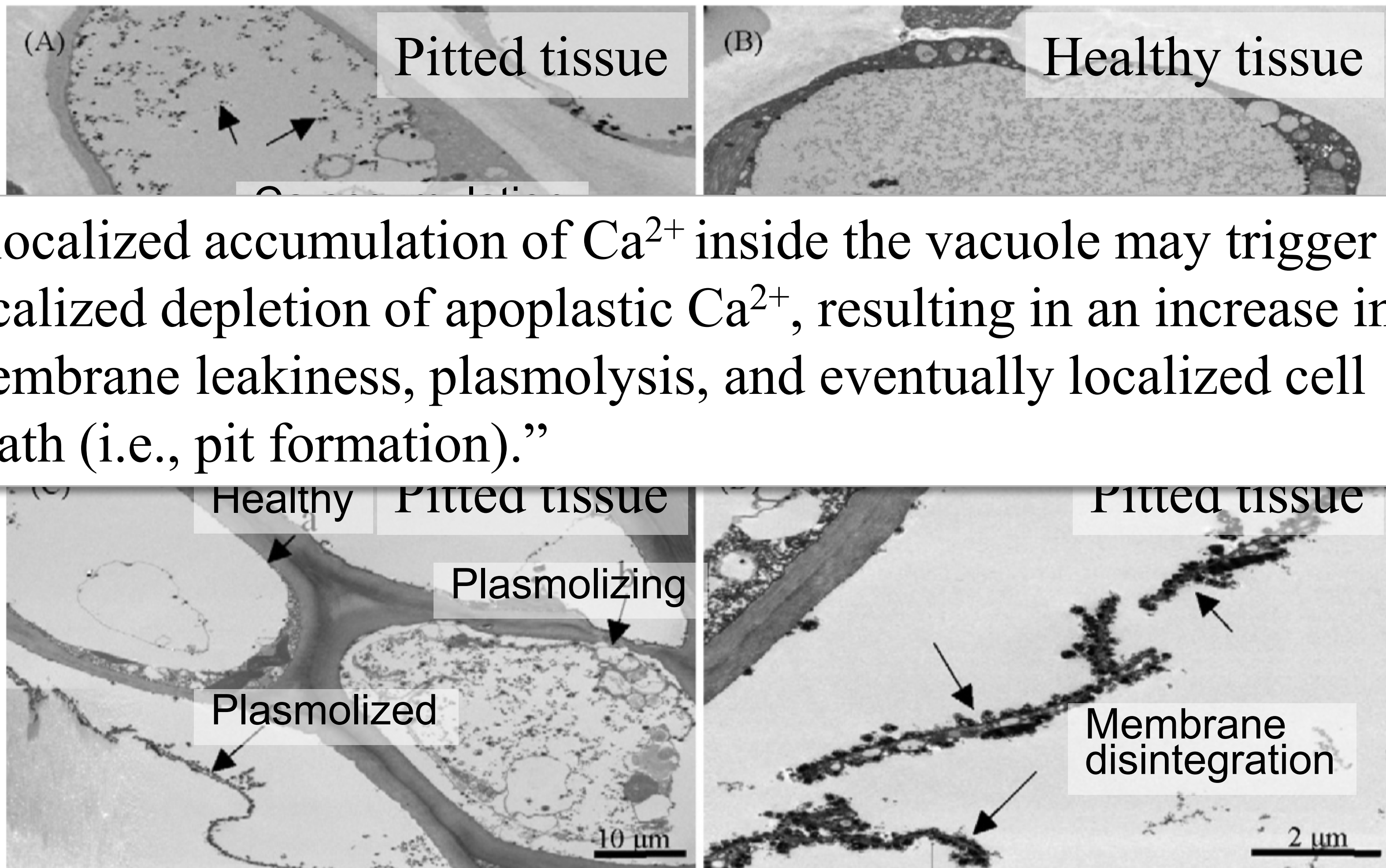


"-localized accumulation of Ca^{2+} inside the vacuole may trigger a localized depletion of apoplastic Ca^{2+}, resulting in an increase in membrane leakiness, plasmolysis, and eventually localized cell death (i.e., pit formation)."

Journal of Horticultural Science (1979) **54** (1) 91–92

Research Note

The distribution of calcium in mature apple fruits having bitter pit disorder

By ELSIE M. FORD
East Malling Research Station, Maidstone, Kent ME19 6BJ, UK

"^{45}Ca, which was fed to the roots in mid-May, accumulated in the pits <u>after</u> the tissues began disintegrating."

"…no accumulations in the cortex were observed unaccompanied by bitter pit."

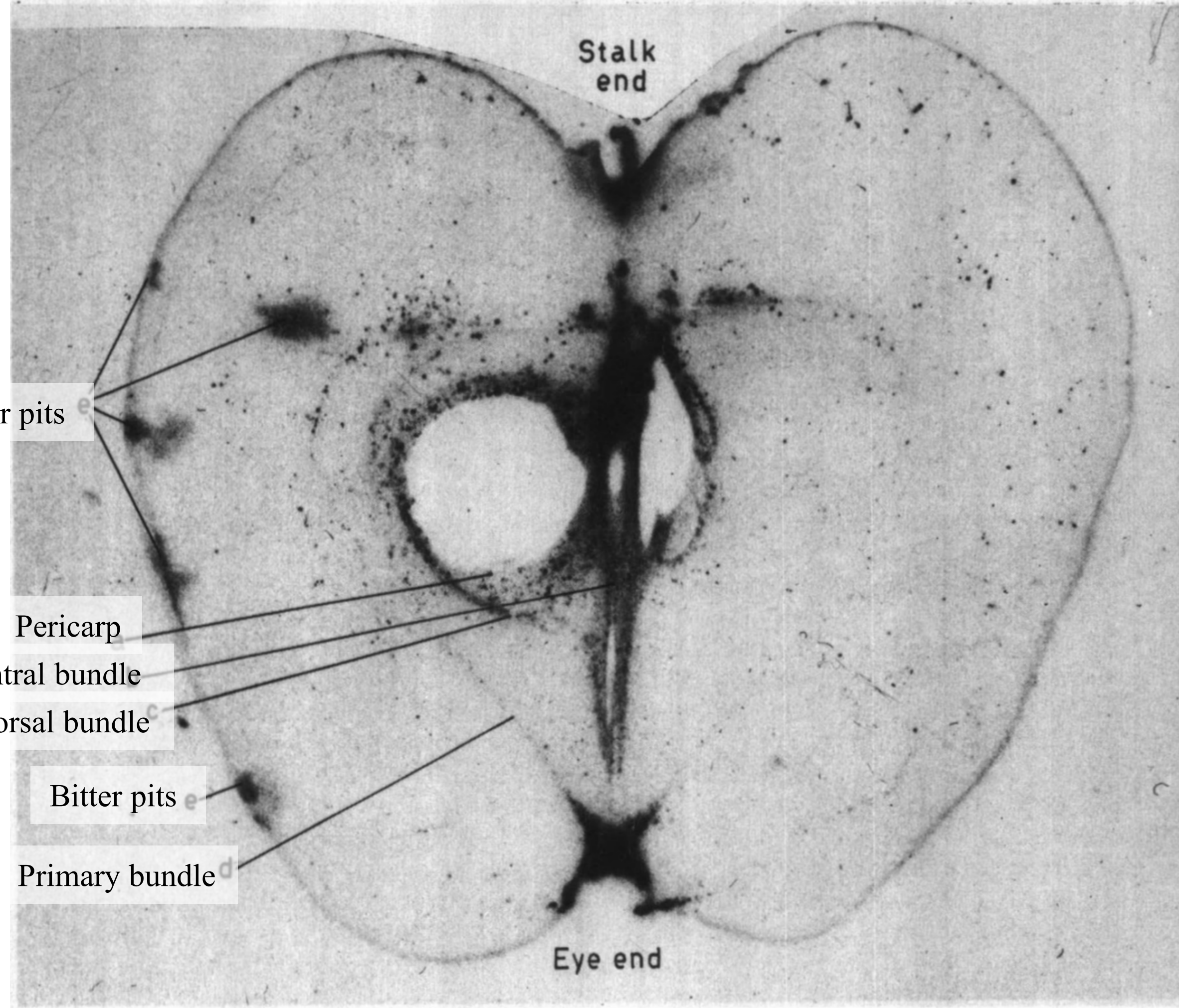


PLATE 1
Longitudinal section of mature Merton Worcester fruit showing areas of bitter pit (e) where ^{45}Ca has collected. a – cartilaginous pericarp, b – ventral carpellary bundles, c – dorsal carpellary bundles, d – sepal or petal bundle, e – accumulations of ^{45}Ca in bitter pits.

Journal of the Horticultural Society of Japan Vol. 39, No. 4

Distribution of ^{45}Ca applied as chloride and hydroxide on the surface of leaves, fruits and twigs of apple tree

Morimasa Seito and Koushiro Nagai
Aomori Apple Experiment Station, Kuroishi, Aomori

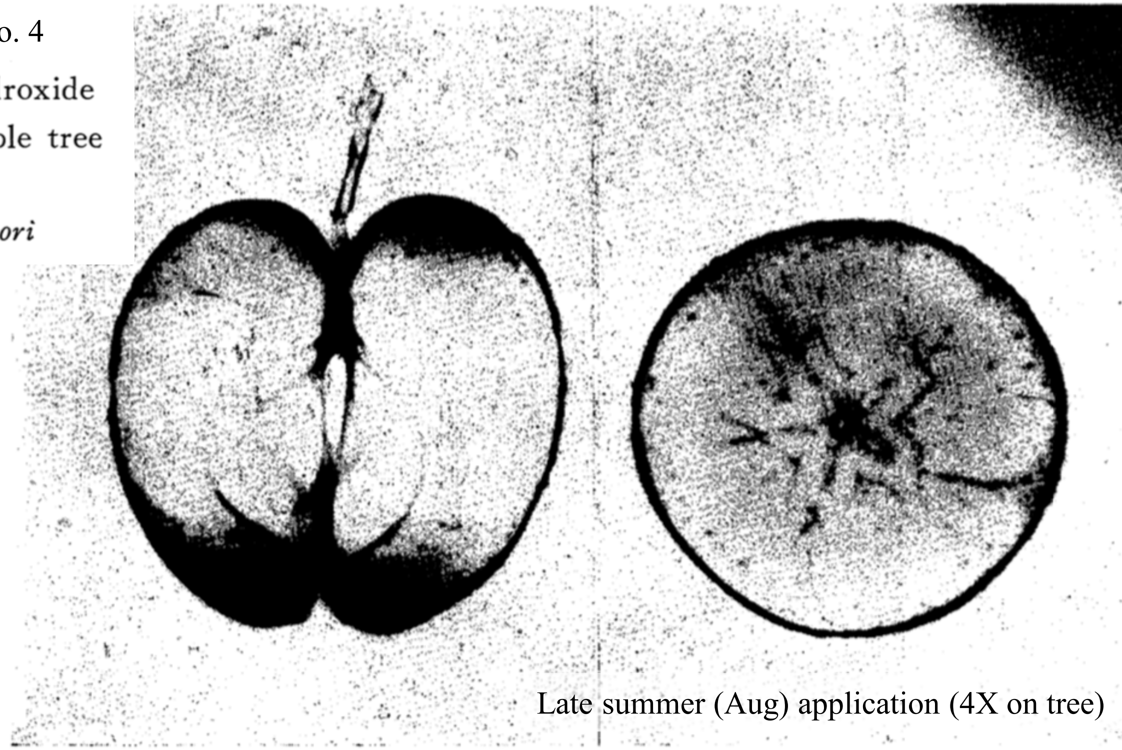


Fig. 3. Autoradiographs of ^{45}Ca distribution in the fruit. The fruit was dipped in $^{45}CaCl_2$ solution and harvested 34 days after the first application.

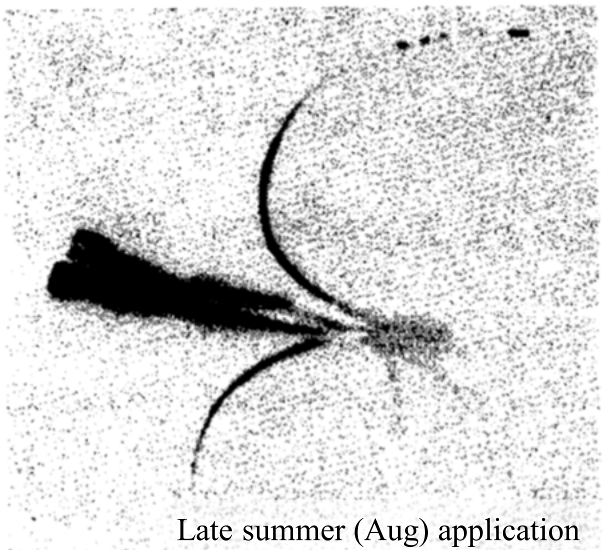


Fig. 2. ^{45}Ca distribution in the fruit. ^{45}Ca was applied as $CaCl_2$ on the adjacent fruit spur leaves and the fruit was harvested 34 days after the first application.

"^{45}Ca applied to the fruit surface by dipping , penetrated to flesh through vascular systems, but radioactivity was greater in skin and core than in flesh."

PHYSIOLOGY OF THE XYLEM

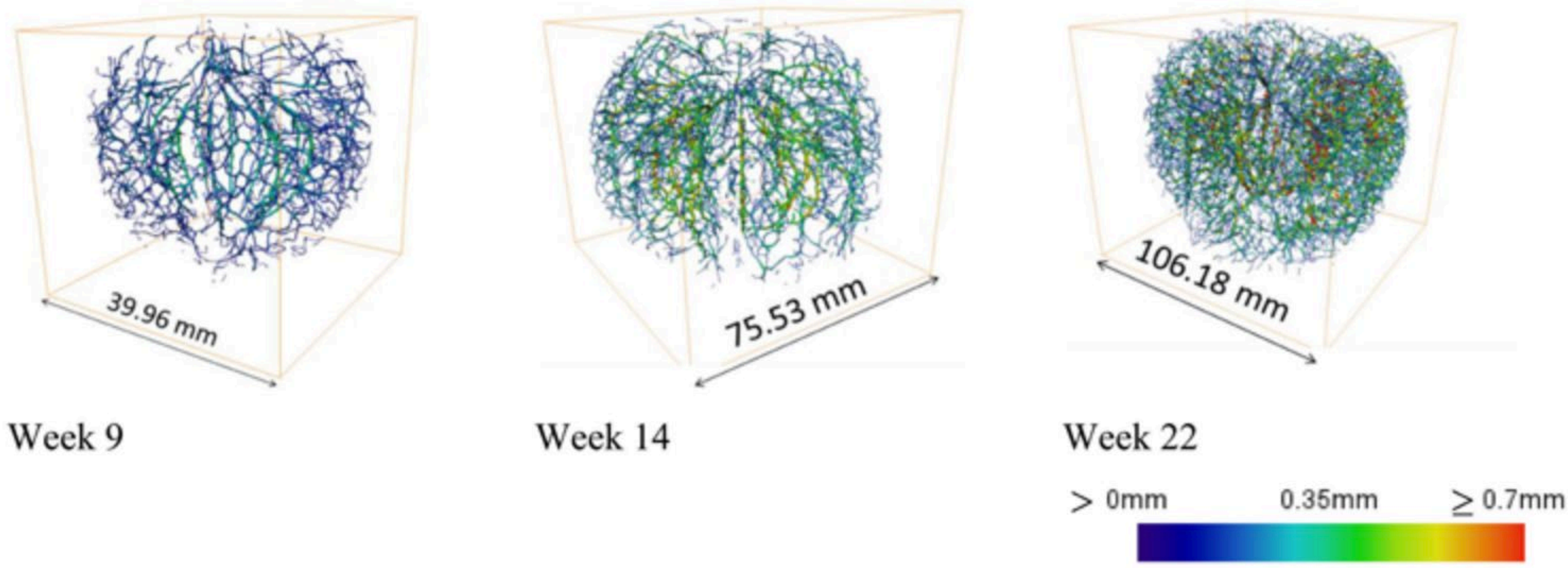
Lee Kalcits, Good Fruit Grower Magazine

METHODS ARTICLE
Front. Plant Sci., 01 September 2015 | https://doi.org/10.3389/fpls.2015.00679

Spatial development of transport structures in apple (*Malus* × *domestica* Borkh.) fruit

Els Herremans[1], Pieter Verboven[1], Maarten L. A. T. M. Hertog[1], Dennis Cantre[1], Mattias van Dael[1], Thomas De Schryver[2], Luc Van Hoorebeke[2] and Bart M. Nicolaï[1,3*]

[1]Division of MeBioS, Department of Biosystems, KU Leuven, University of Leuven, Leuven, Belgium
[2]Department of Physics and Astronomy, UGCT-Radiation Physics, Ghent University, Ghent, Belgium
[3]Flanders Centre of Postharvest Technology, Leuven, Belgium



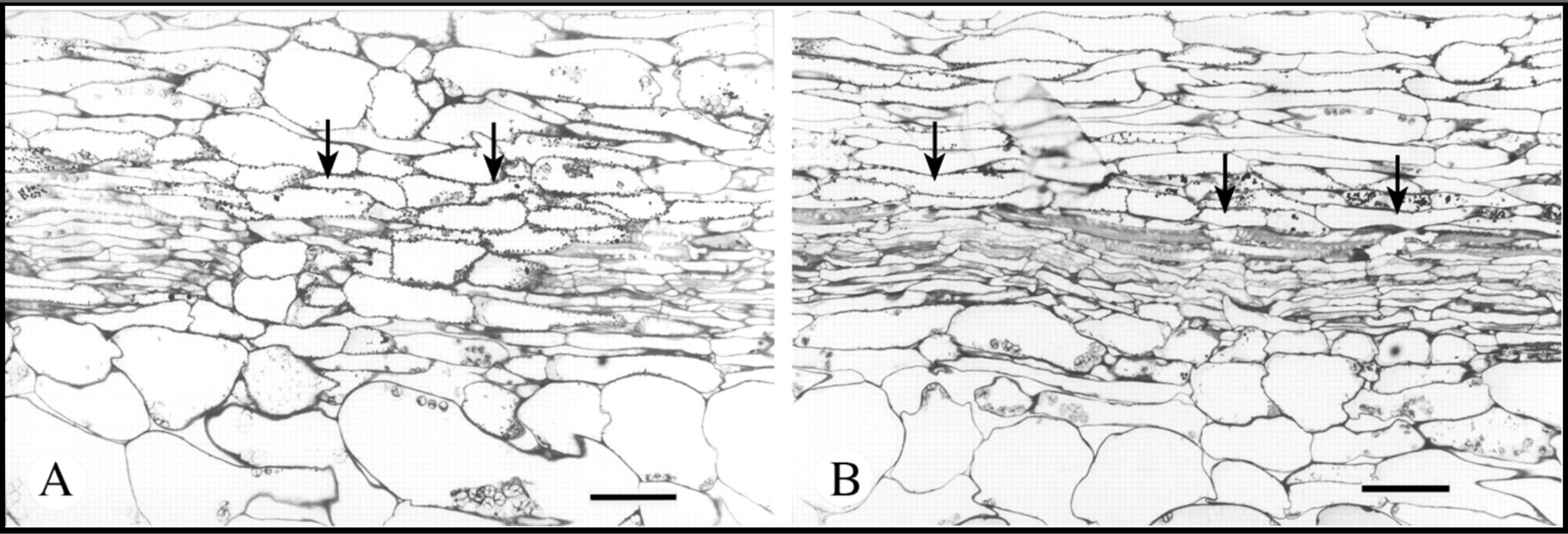
Cortical vascular networks 9, 14, and 22 weeks after bloom. Colors indicate thickness of the vasculature

Causes and Effects of Changes in Xylem Functionality in Apple Fruit FREE

LAZAR DRAŽETA, ALEXANDER LANG, ALISTAIR J. HALL, RICHARD K. VOLZ, PAULA E. JAMESON

Annals of Botany, Volume 93, Issue 3, March 2004, Pages 275–282, https://doi-org.proxy2.cl.msu.edu/10.1093/aob/mch040

Published: 01 March 2004



Breakage of the xylem strand Ruptured string of vessels

"-xylem dysfunction could be seen as minimizing outflowing xylem sap from the fruit, but at the expense of reduced import of xylem-borne minerals, such as calcium, to the fruit"

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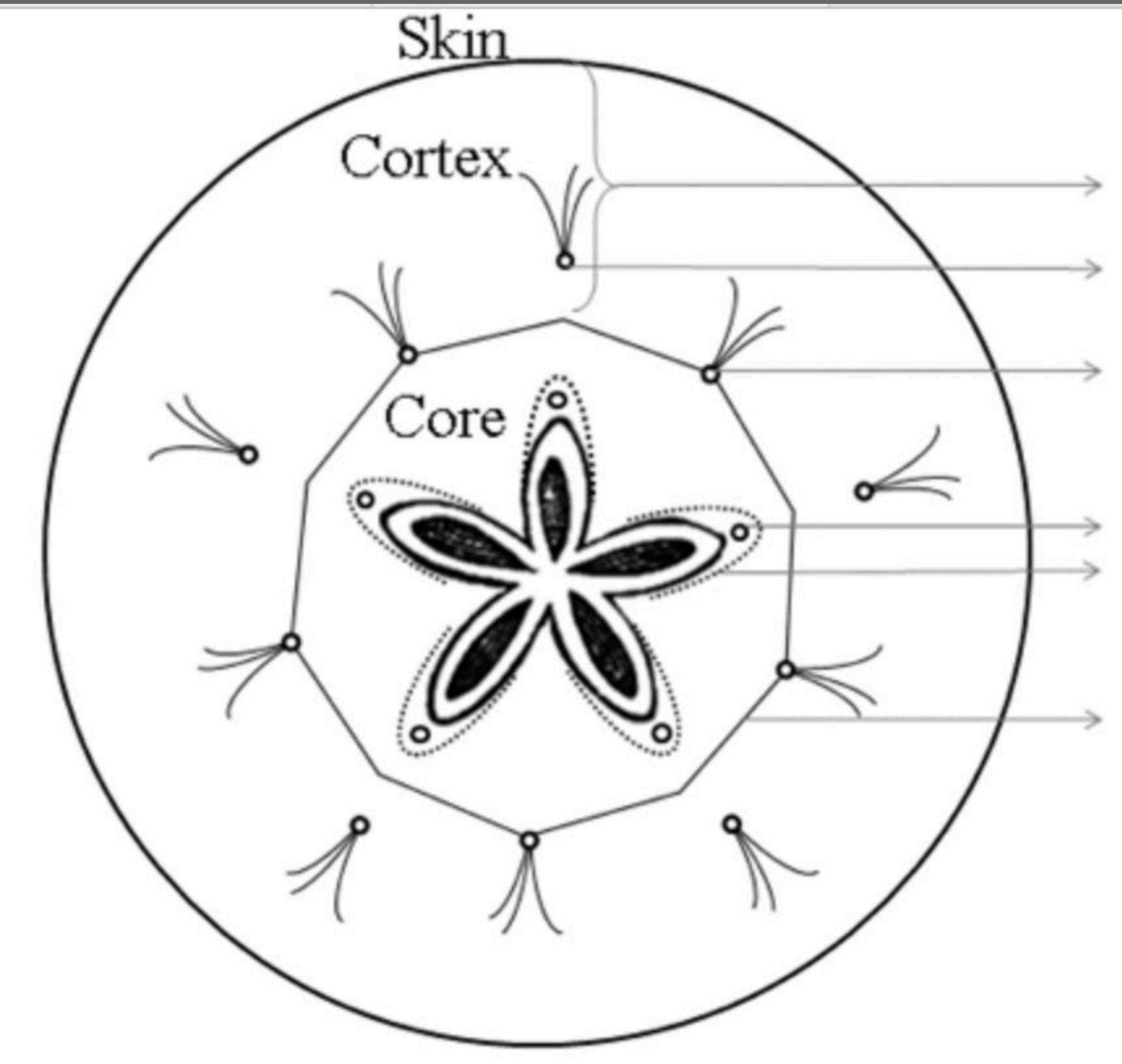

Floral tube
Sepal (primary) bundles

Petal (primary) bundles

Dorsal carpellary bundles
Ventral carpellary bundles

Outer limit of carpel (core)

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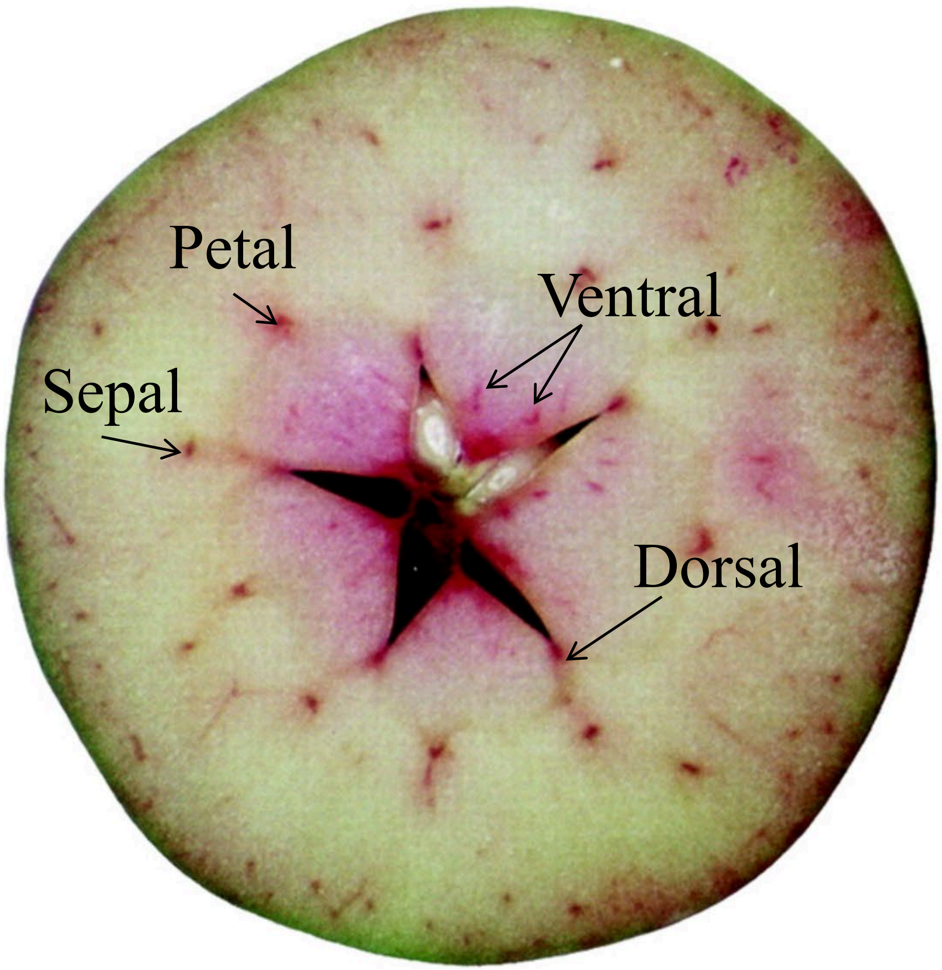
Staining: 1 % w/w aqueous acid fuchsin was drawn up into the fruit through the stalk for 2 h under 22 ° C and 65 % RH with a brisk airflow.



Braeburn (64 DAFB)

Granny Smith (67 DAFB)

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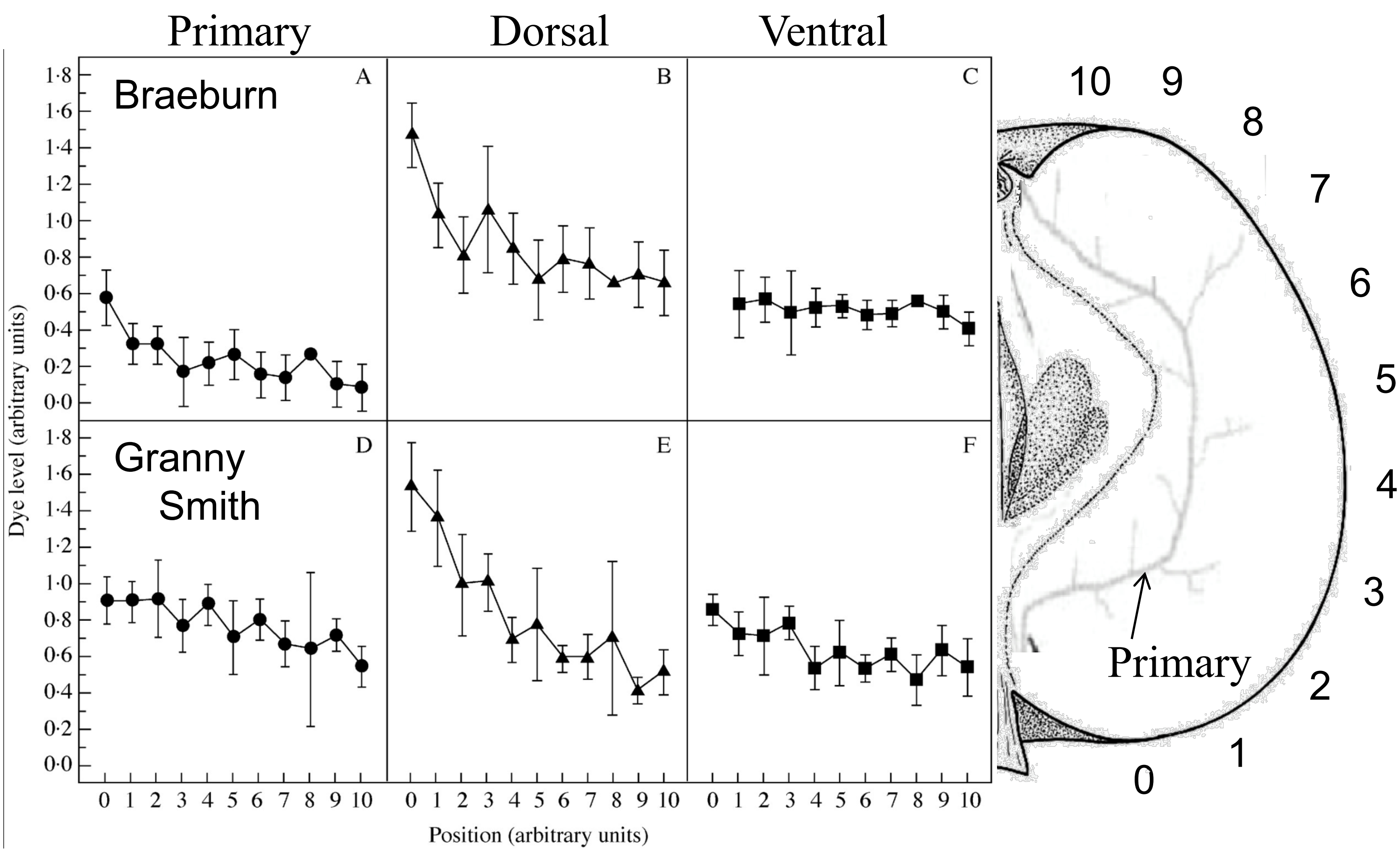

Longitudinal changes in the functionality of xylem

Dražeta et al., 2004

Causes and Effects of Changes in Xylem Functionality in Apple Fruit

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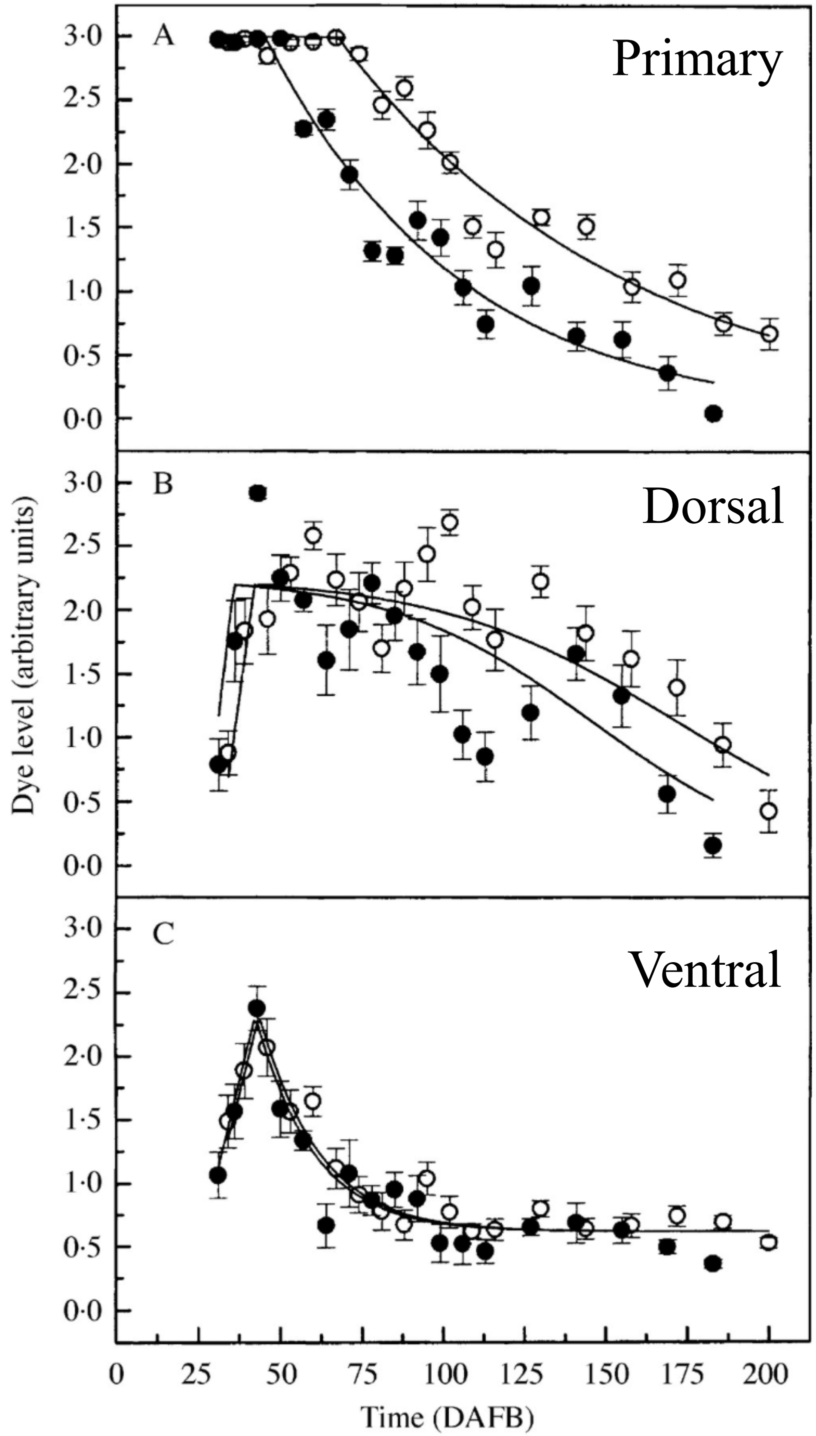
Dye level in 'Braeburn' (solid circles) and 'Granny Smith' (open circles) as a function of fruit age (DAFB).



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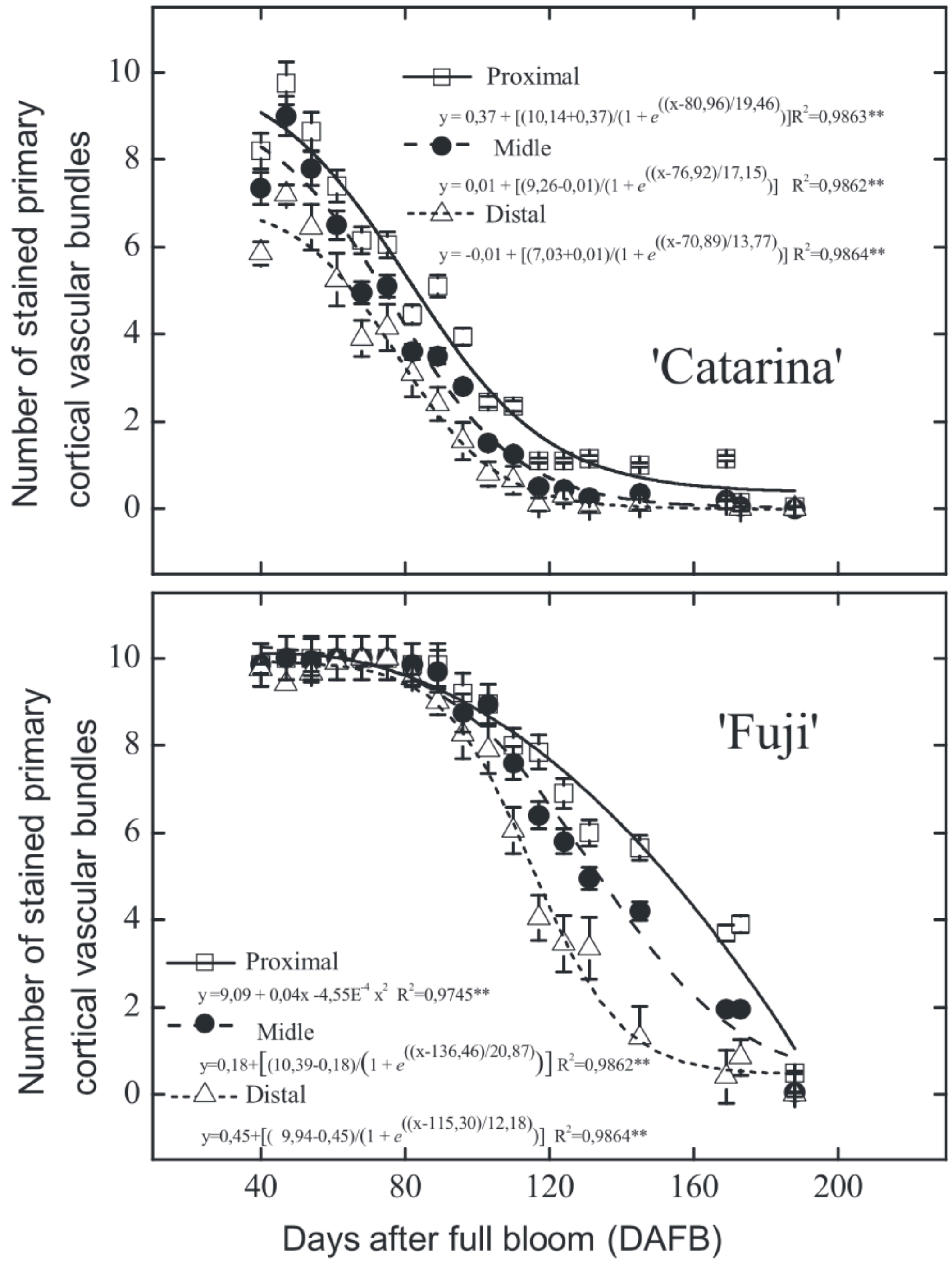
Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Relationship between xylem functionality, calcium content and the incidence of bitter pit in apple fruit

Aquidauana Miqueloto[a,*], Cassandro Vidal Talamini do Amarante[a], Cristiano André Steffens[a], Aline dos Santos[a], Elizabeth Mitcham[b]

[a] Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinárias, Av. Luiz de Camões, 2090, Lages, SC, CEP 88520-000, Brazil
[b] Department of Plant Sciences, University of California, Davis, CA, USA



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Published: 01 March 2004

"A variable timing of xylem dysfunction could…create high variability in fruit mineral composition.

This could explain the high variability observed in the incidence of calcium-related disorders, such as bitter pit.

Hence, the earlier start of xylem dysfunction in 'Braeburn' fits with the observation that, of the two cultivars examined, 'Braeburn' is the more susceptible to bitter pit."

SEQUENCE OF EVENTS

Ca uptake – first 6 to 7 weeks

Xylem disruption

Initiation events (???)

Ca^{++} partitioning to vacuoles

Cell collapse, cell wall thickening

Cell death and pit formation

Accumulation of Ca^{++} and Mg^{++}

Maybe….

Bitter Pit in Apple Fruit

Horticultural Reviews
Edited by Jules Janick

1989

I. B. Ferguson and C. B. Watkins
Division of Horticulture & Processing
Department of Scientific & Industrial Research
Private Bag, Auckland
New Zealand

CONCLUSIONS

1. Not enough is known about the development of Ca deficiency and mineral imbalance in the fruit, particularly about the input of minerals into the developing fruit in terms of fruit growth, transport processes, and internal distribution of minerals.

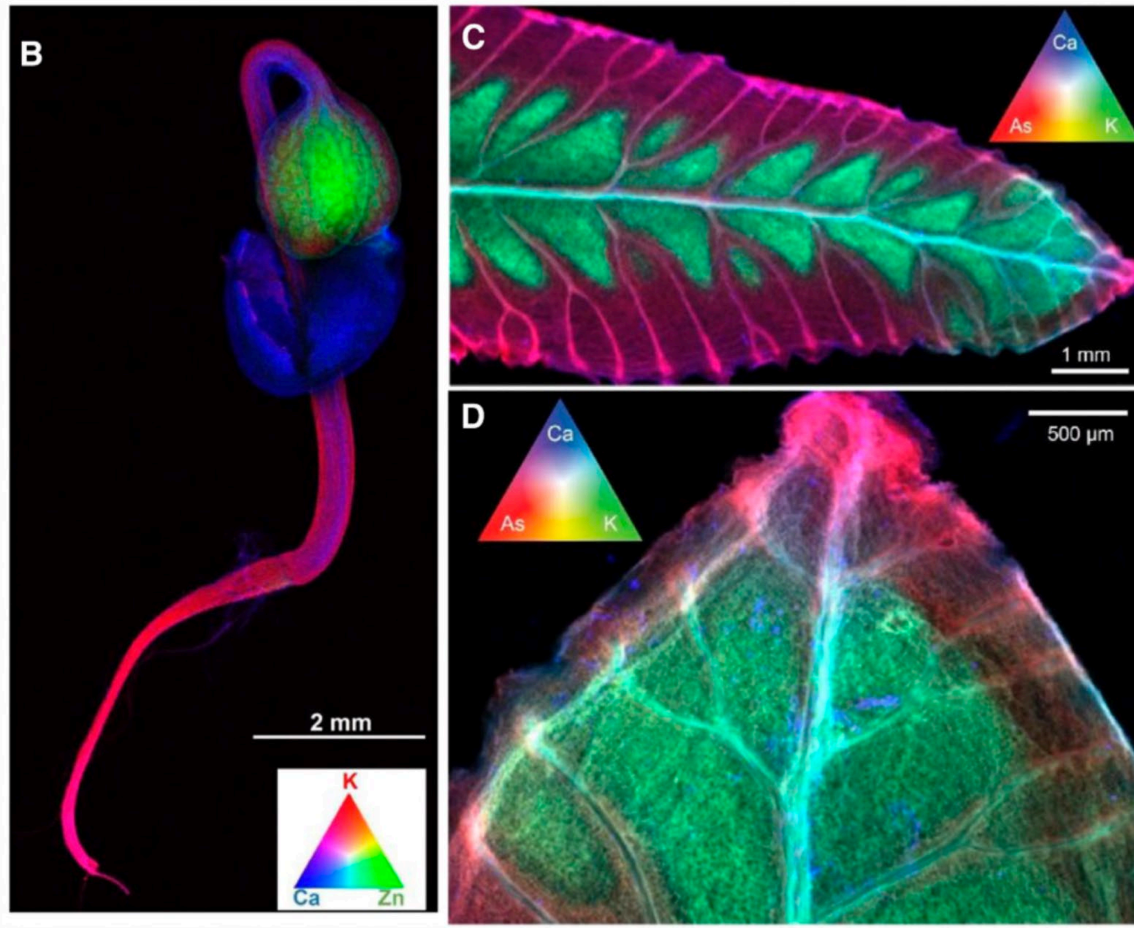
2. There is poor understanding of the localization of bitter pit symptoms in the fruit flesh. This includes the identification of potential sites of pitting in terms of both minerals and cell metabolism.

Plant Physiology, 2018

Synchrotron-Based X-Ray Fluorescence Microscopy as a Technique for Imaging of Elements in Plants[1[OPEN]]

Peter M. Kopittke,[a] Tracy Punshon,[b] David J. Paterson,[c] Ryan V. Tappero,[d] Peng Wang,[e,f,2] F. Pax C. Blamey,[a] Antony van der Ent,[g] and Enzo Lombi[h,3]

"XFM offers…*in vivo* analyses at room temperature and pressure, good detection limits (approximately 1–100 mg kg^{-1}), and excellent resolution (down to 50 nm)."



Bitter Pit in Apple Fruit

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1989

CONCLUSIONS

3. There is a lack of appreciation of the metabolic components of bitter pit. This is current both in the role of Ca in cell metabolism, and in the metabolic events exclusive of mineral metabolism, which might initiate bitter pit development. There is a need to reinterpret all Ca deficiency disorders in the light of the latest developments in the physiology and biochemistry of Ca in plant tissues.

4. Although differences in cultivar susceptibility are well known, the possibilities of genetic control of bitter pit and other storage disorders have not been exploited.

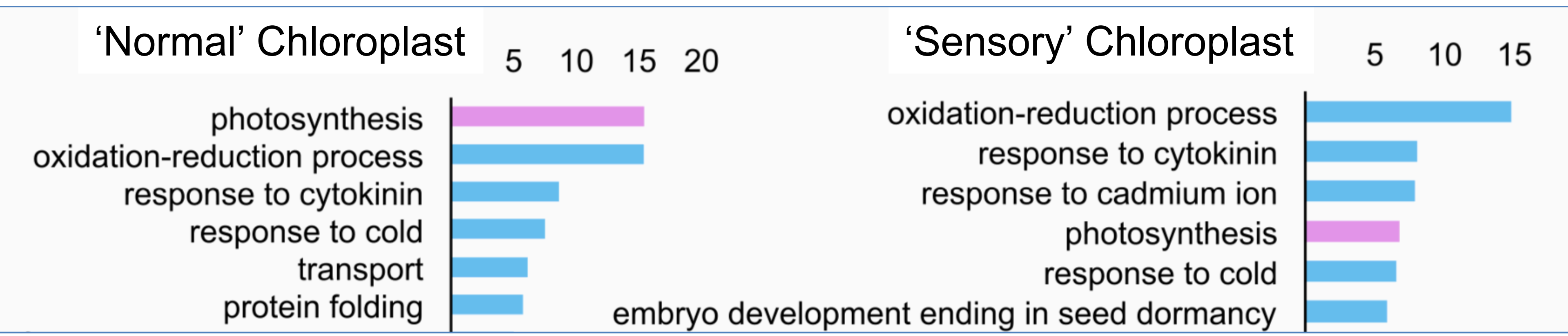
Specialized Plastids Trigger Tissue-Specific Signaling for Systemic Stress Response in Plants[1[OPEN]]

Jesús Beltrán,[a,b] Yashitola Wamboldt,[b] Robersy Sanchez,[a] Evan W. LaBrant,[b] Hardik Kundariya,[a] Kamaldeep S. Virdi,[b] Christian Elowsky,[b] and Sally A. Mackenzie[a,2,3]

[a]Departments of Biology and Plant Science, The Pennsylvania State University, University Park, Pennsylvania 16802
[b]Department of Agronomy and Horticulture, University of Nebraska, Lincoln, Nebraska 68588

"These plastids are termed "sensory" plastids, and here we show their proteome to be distinct from chloroplasts."

"We posit that the sensory plastid participates in sensing environmental stress, integrating this sensory function with epigenetic and gene expression circuitry to condition heritable stress memory."



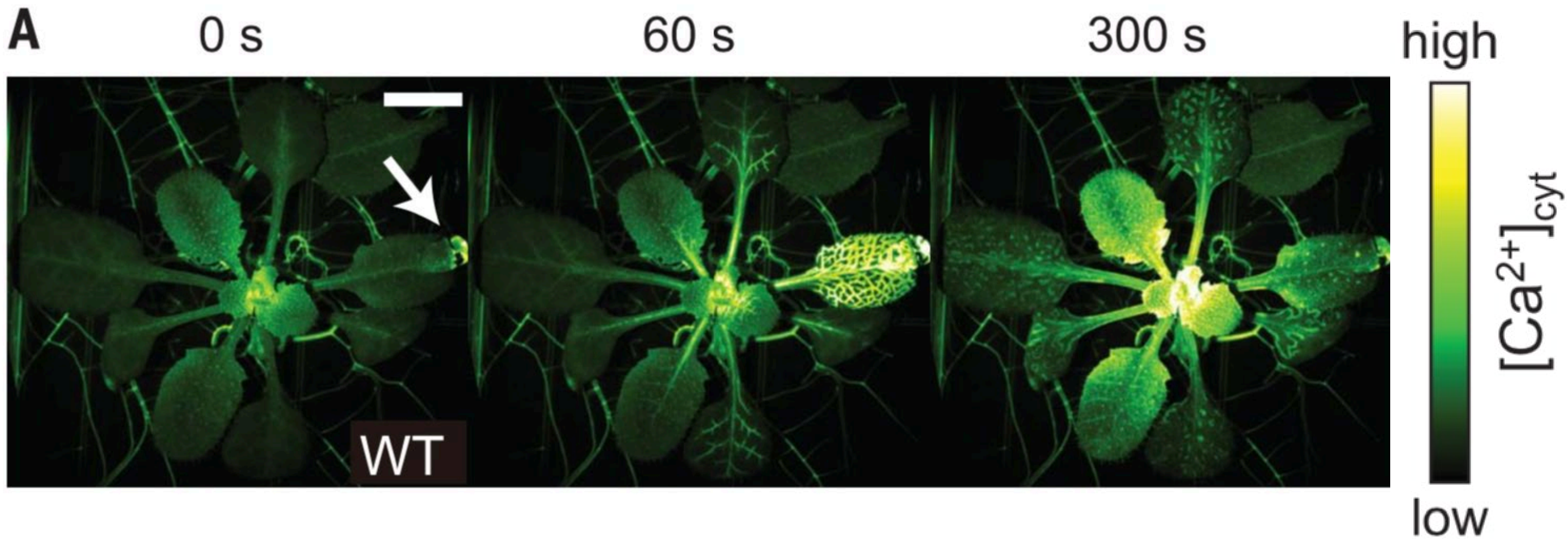
RESEARCH

BOTANY

Science, 2018

Glutamate triggers long-distance, calcium-based plant defense signaling

Masatsugu Toyota[1,2,3]*, Dirk Spencer[2]†, Satoe Sawai-Toyota[2]‡, Wang Jiaqi[1], Tong Zhang[4,5]§, Abraham J. Koo[4,5], Gregg A. Howe[6,7], Simon Gilroy[2]*



"Ion channels of the GLUTAMATE RECEPTOR– LIKE family act as sensors that convert this signal into an increase in intracellular calcium ion concentration that propagates to distant organs, where defense responses are then induced."

“In neuroscience, **glutamate** is a neurotransmitter: a chemical that nerve cells use to send signals to other cells. It is by a wide margin the most abundant excitatory neurotransmitter in the vertebrate nervous system.”

QUESTIONS/DISCUSSION POINTS...

1. Can we predict bitter pit?
2. When does bitter pit ‘begin’?
3. What are the connections between weather and bitter pit?
4. Is there a physiological signal to trigger bitter pit?
5. Can we develop a model system for the study of bitter pit?
6. What causes bitter pit?

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Thanks!

Department of Horticulture
Michigan State University