WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

Linking Fruit and Soil Quality (Health)

Preston Andrews, Ph.D.
Horticulture

IFTA Annual Conference, March 2, 2011

Pasco, Washington

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Overview

- Definitions of fruit & soil quality (health)
- Historical perspective of emphasis on inorganic over organic fertilizers
- “Living soil” - carbon & nitrogen cycles
- Three studies:
  Apple, strawberry & tomato
- Characteristics of “living soil” & conclusions

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Fruit quality

Standards that distinguish fruit as superior

- size
- color
- firmness
- sugars & acids
- dry matter & water content
- sensory (sweetness, tartness, texture, aroma, flavor)
- nutritional value (vitamins, minerals, phytochemicals)
- keeping qualities (storage, shelf-life, etc.)

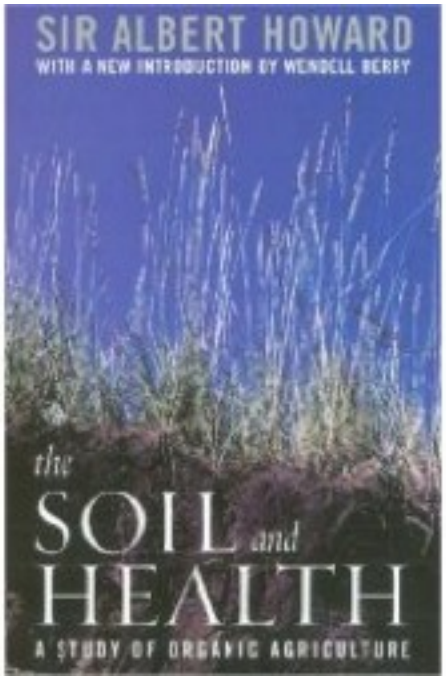
Soil quality (health)

"…capacity of a soil to function within ecosystem boundaries (limits, capacity) to sustain biological productivity, maintain environmental quality, and promote plant…health." Doran & Parkin (1994)

- **accommodate water entry & facilitate water movement & availability**
- **resist structural degradation**
- **sustain productivity & fruit quality**

Indicators: pH, EC, CEC, bulk density, aggregate stability, porosity, hydrated pore space, N-P-K etc., organic carbon, microbial biomass, earthworms, food web, others

1943

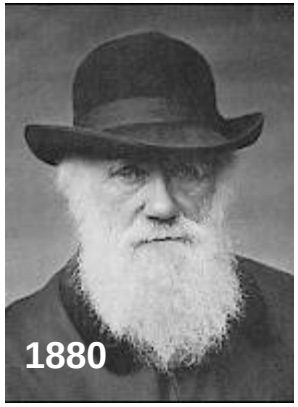


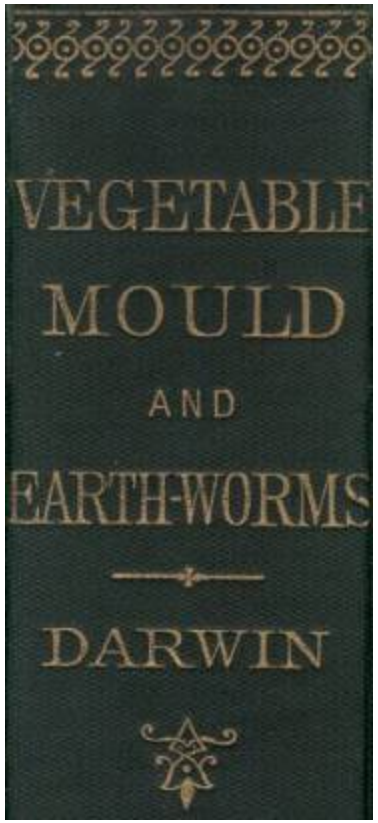
1947

"Living soil" refers to the "biologically regulated interconnections in the soil ecosystem [that] play key roles in maintaining desirable soil physical and chemical conditions."

Kristiansen & Merfield, *Organic Agriculture: A Global Perspective* (2006)

Charles Darwin
1809-1882





- Published 1881
- Based on life-long study
- Habits & effects of earthworms

"Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds…like a gardener who prepares fine soil…In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification." (pp. 309-10)

Justus von Liebig
1803-1873

CHEMISTRY

IN ITS APPLICATION TO

AGRICULTURE AND PHYSIOLOGY.

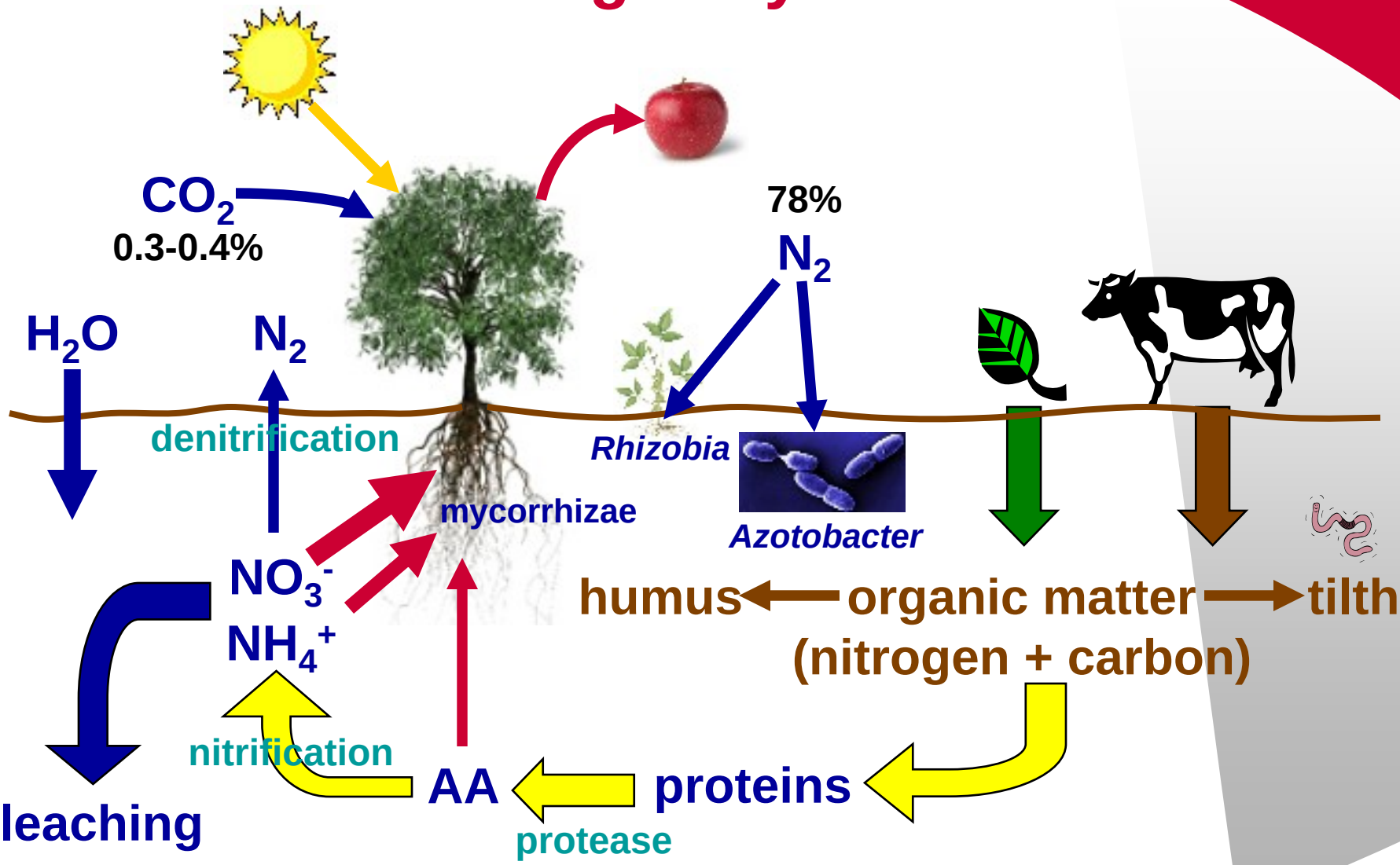
BY JUSTUS LIEBIG, M.D., PH.D. F.R.S., M.R.I.A.,

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF GIESSEN; KNIGHT OF THE HESSIAN ORDER, AND OF THE IMPERIAL ORDER OF SAINT ANN; MEMBER OF THE ROYAL ACADEMY OF SCIENCES OF STOCKHOLM; CORRESPONDING MEMBER OF THE ROYAL ACADEMIES OF SCIENCES OF BERLIN AND MUNICH; OF THE IMPERIAL ACADEMY OF ST. PETERSBURGH; OF THE ROYAL INSTITUTION OF AMSTERDAM, ETC. ETC.

- German chemist
- Downplayed soil humus
- Ammonia & inorganic minerals more important
- Substituted chemical fertilizers for biologically based soil fertility

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Carbon and nitrogen cycles



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Three Studies

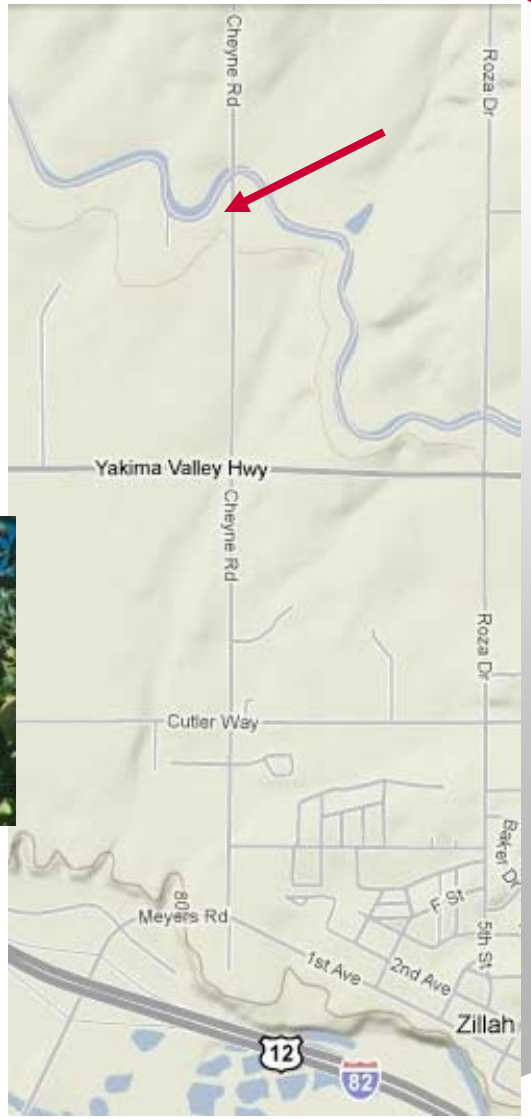
Apples

Strawberries

Tomatoes

Washington apple study

- virgin pasture site
- planted 1994, study ended 2003
- Golden Delicious grafted to Gala
- randomized complete block
- managed by the grower



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Sustainability of three apple production systems

John P. Reganold*, Jerry D. Glover*, Preston K. Andrews† & Herbert R. Hinman‡

- crop quality
- soil quality
- profitability
- environmental impact
- energy efficiency

HortScience 41(1):99–107. 2006.

Apple Orchard Productivity and Fruit Quality under Organic, Conventional, and Integrated Management

Gregory M. Peck[1]
Department of Horticulture and Landscape Architecture, Washington State University, Pullman, WA 99164-6414

Preston K. Andrews
Department of Horticulture and Landscape Architecture, Washington State University, Pullman, WA 99164-6414

John P. Reganold
Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420

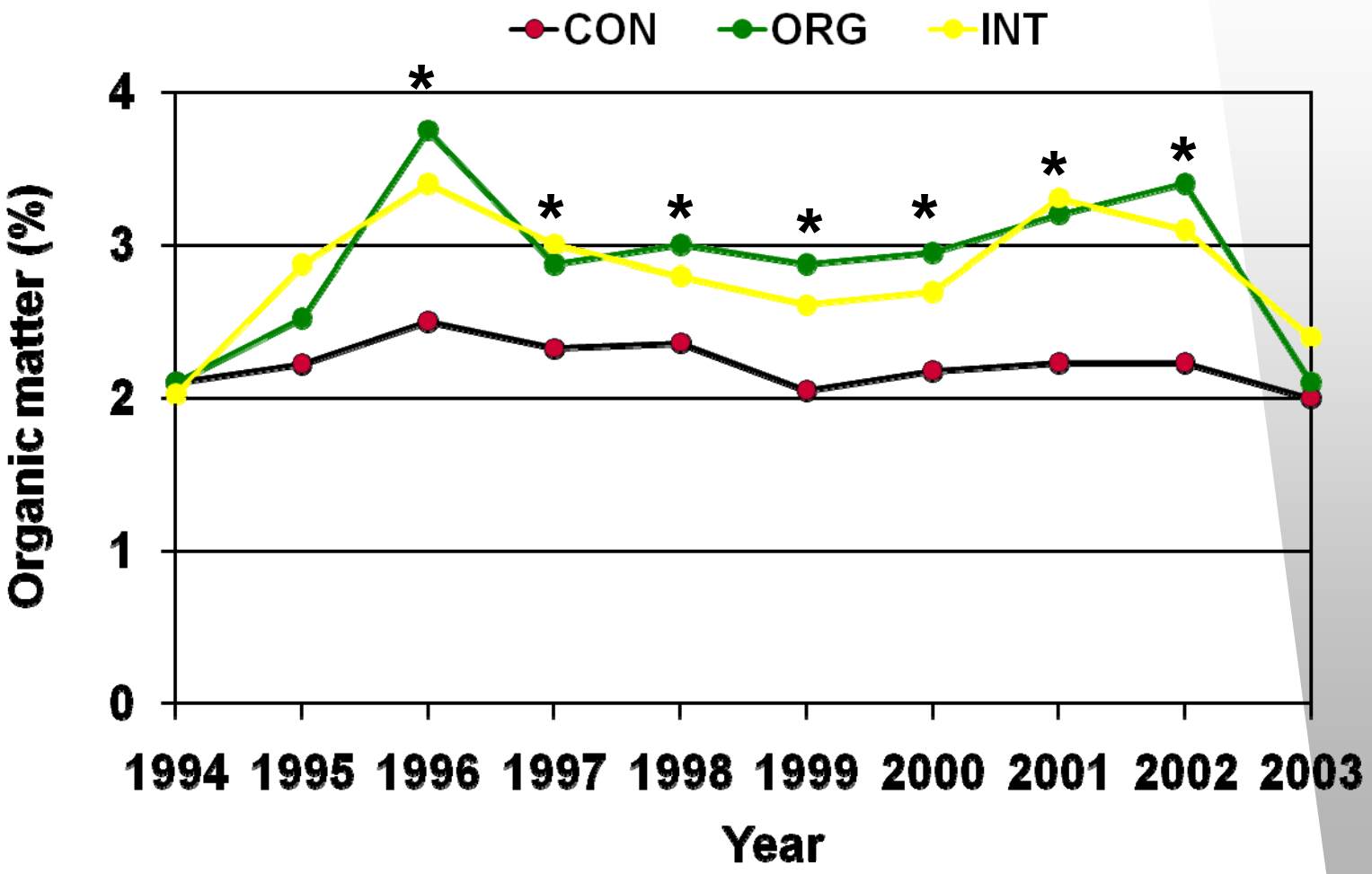
John K. Fellman
Department of Horticulture and Landscape Architecture, Washington State University, Pullman, WA 99164-6414

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Year	Conventional	Organic	Integrated
1994	$Ca\text{-}NO_3$ Roundup	Poultry compost Bark mulch	$Ca\text{-}NO_3$, compost Bark mulch, Roundup
1995	$Ca\text{-}NO_3$ Roundup	Poultry compost Woven fabric	$Ca\text{-}NO_3$, compost Roundup
1996	Roundup	Woven fabric	Roundup
1997	Roundup	Cultivator	Roundup
1998	Roundup, Simazine	Cultivator	Roundup
1999		Mowed	
2000	$Ca\text{-}NO_3$	Bloodmeal	Ca-NO3, bloodmeal
2001	$Ca\text{-}NO_3$	Bloodmeal	
2002	Roundup, Simazine, Diuron	Ryegrass, vetch, clover Flaming, mowed	Roundup
2003	$NH_4\text{-}SO_4$ Roundup	Clover, bloodmeal Tilled, mowed	$NH_4\text{-}SO_4$

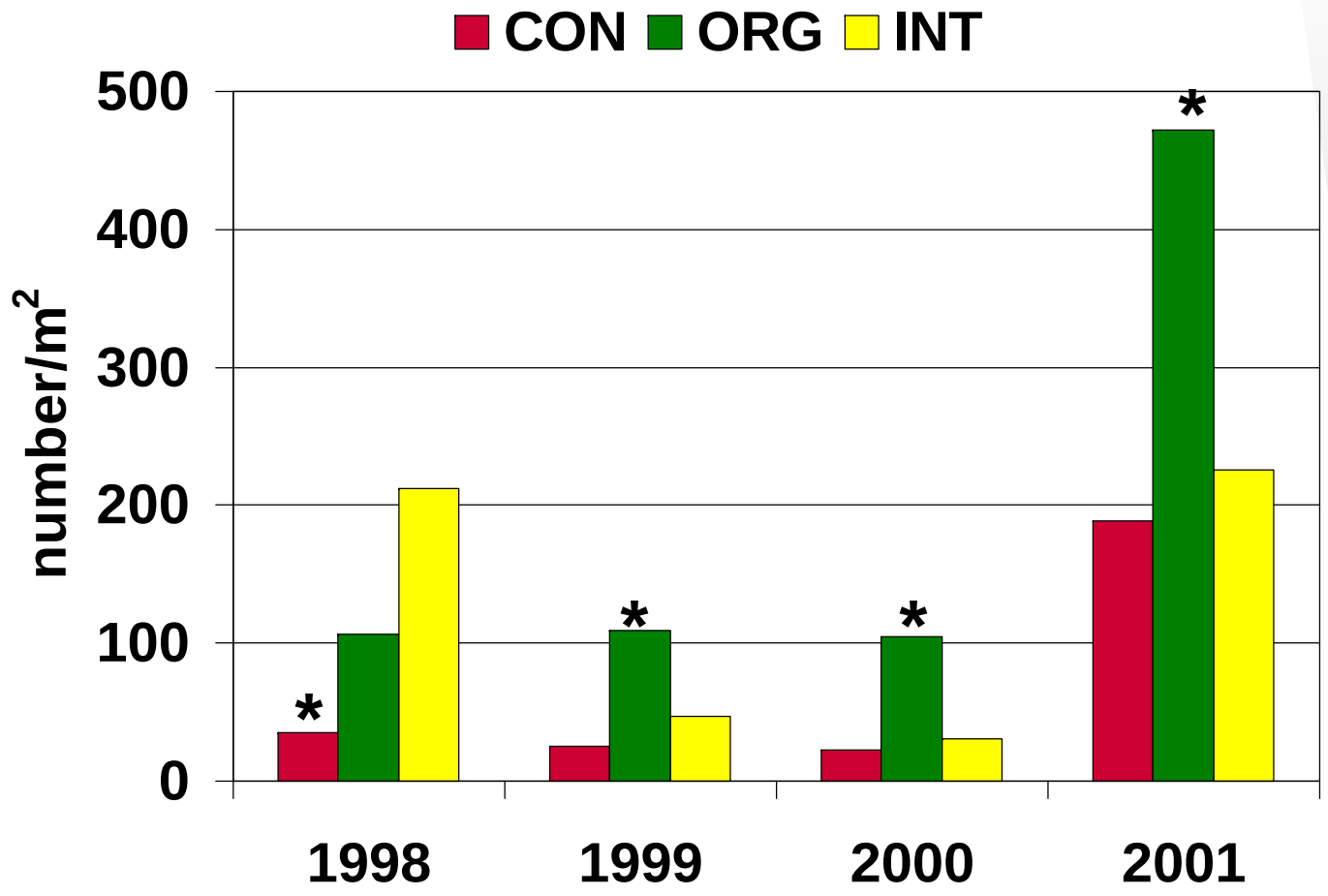
Soil organic matter

Topsoil



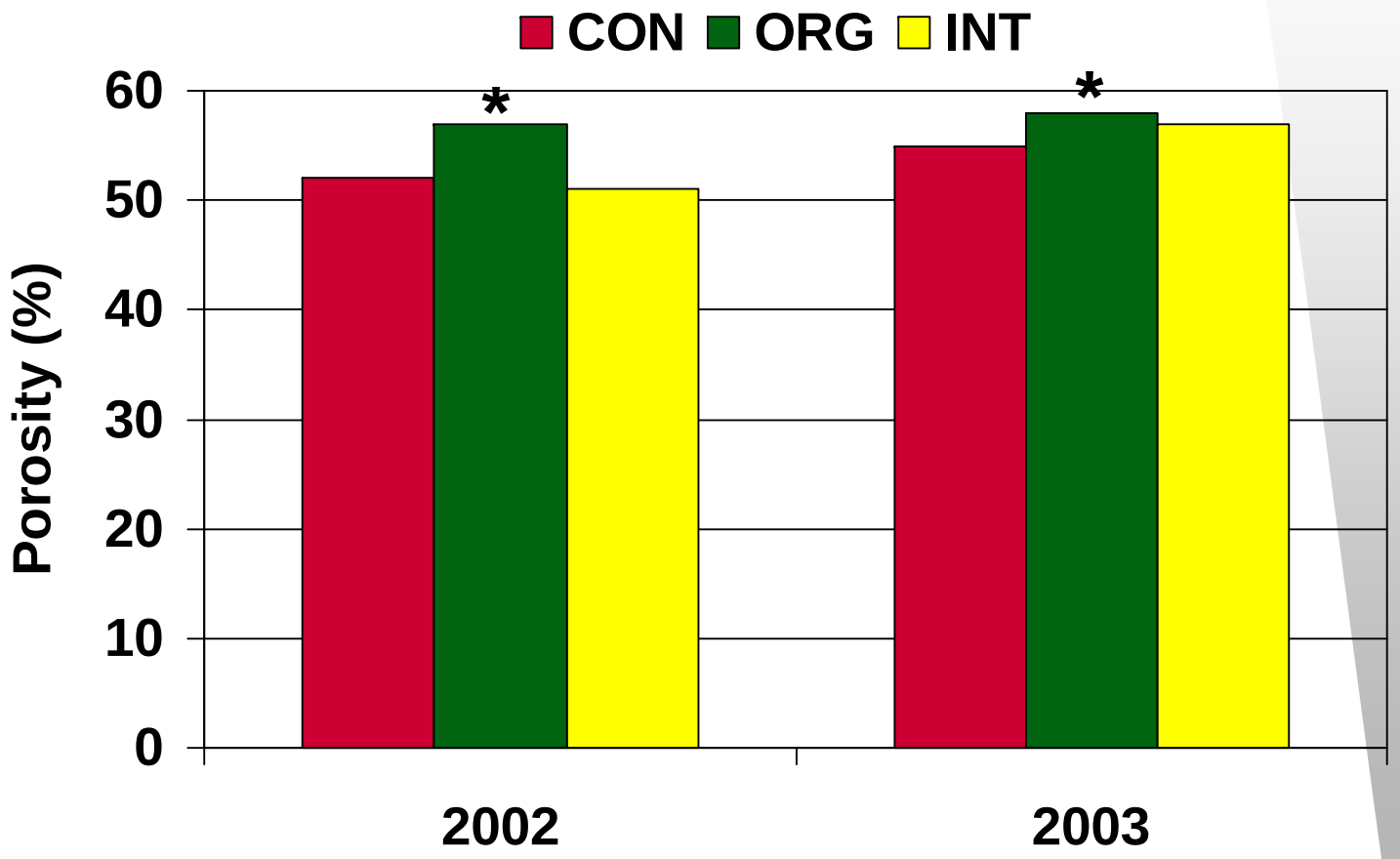
Earthworms

Topsoil



Soil porosity

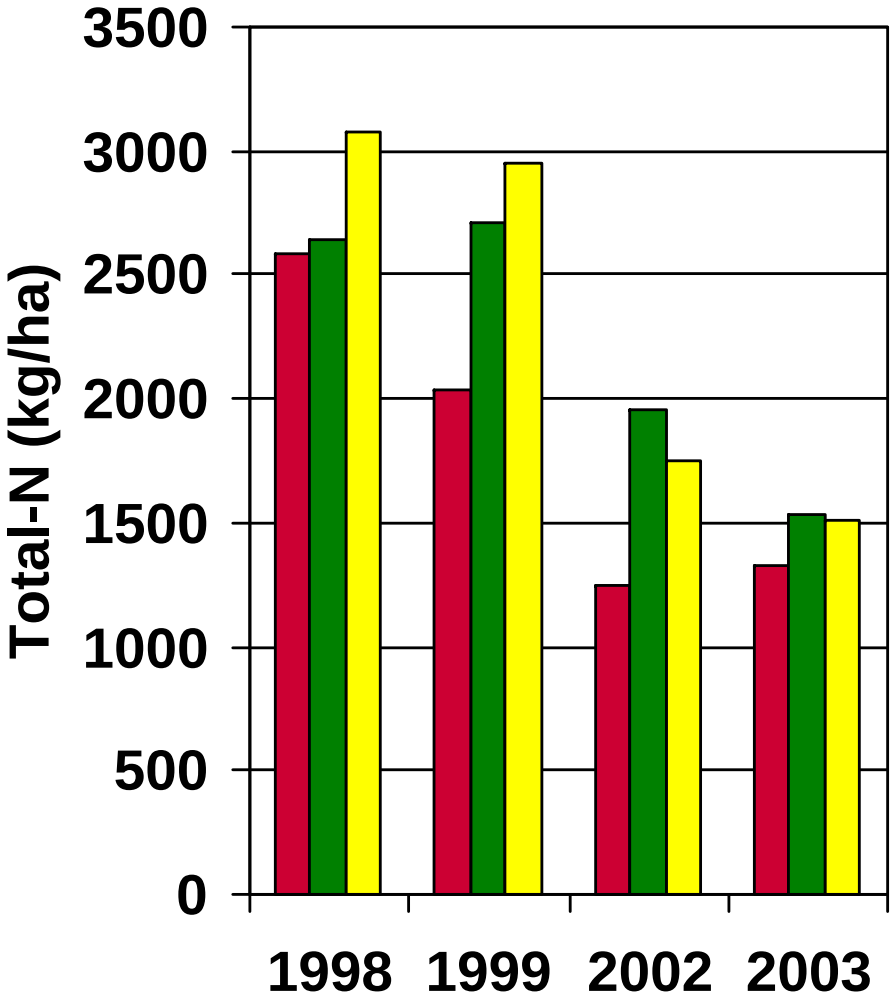
Topsoil



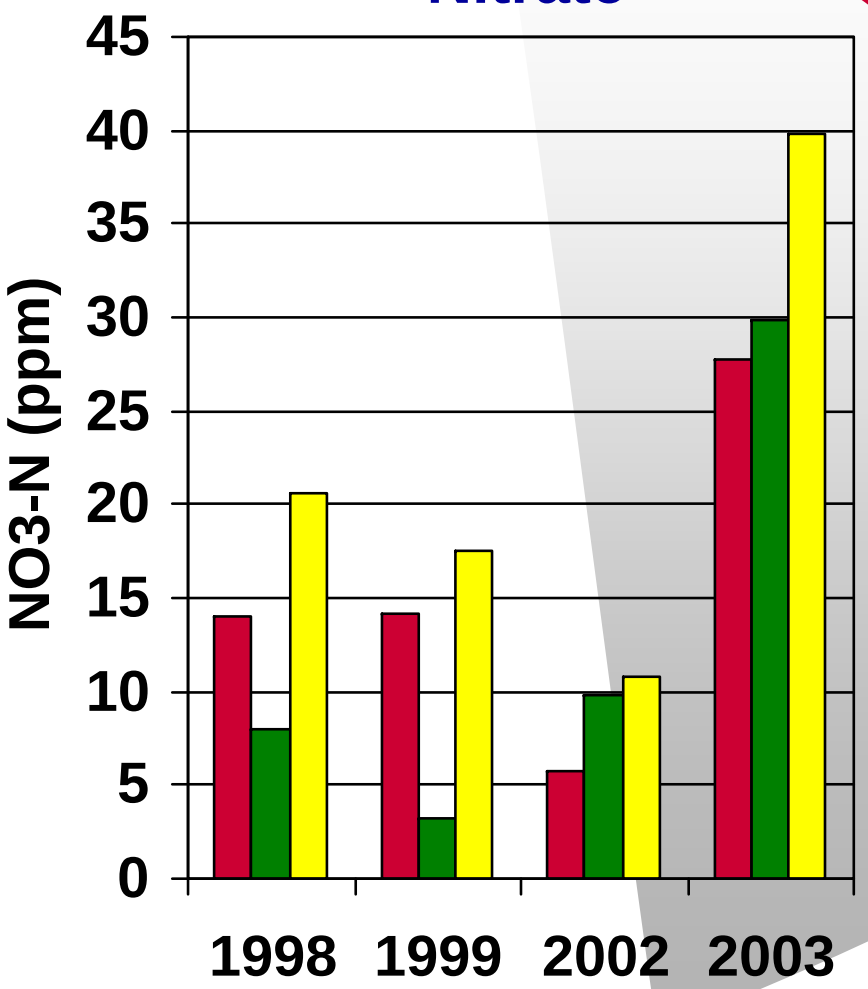
Soil nitrogen

Topsoil

Total



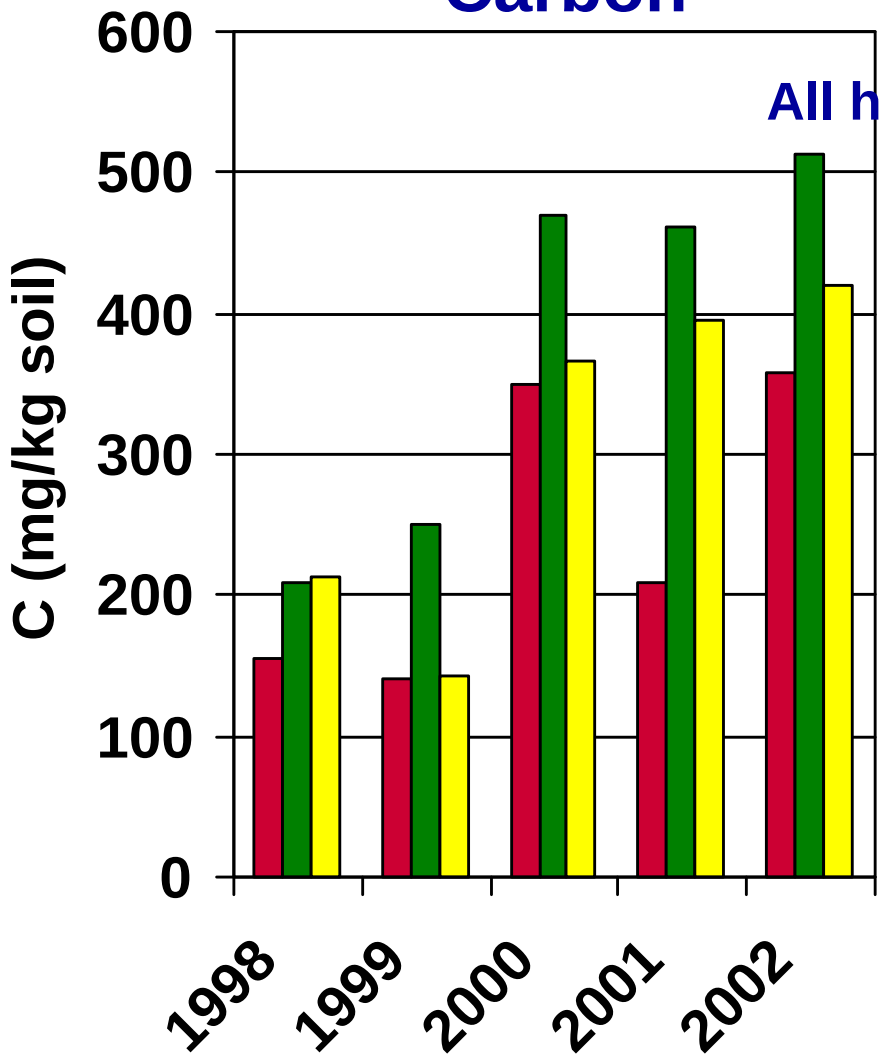
Nitrate



Microbial biomass

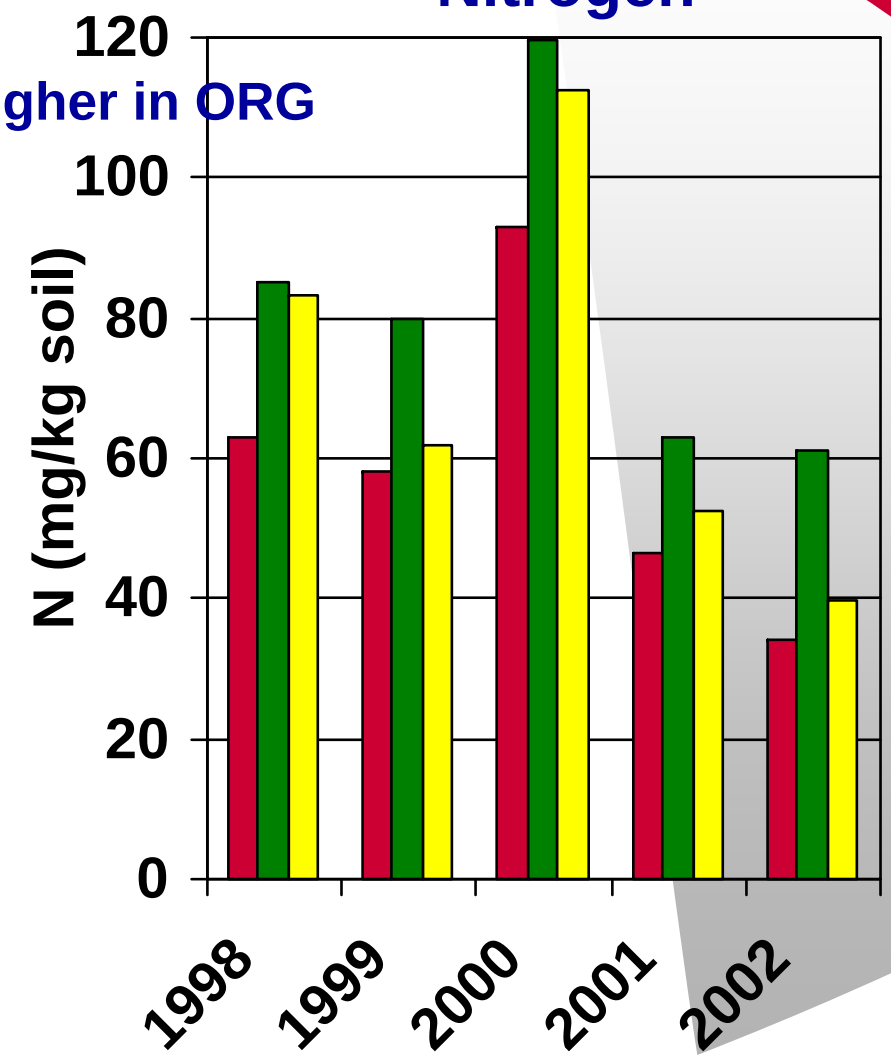
Topsoil

Carbon



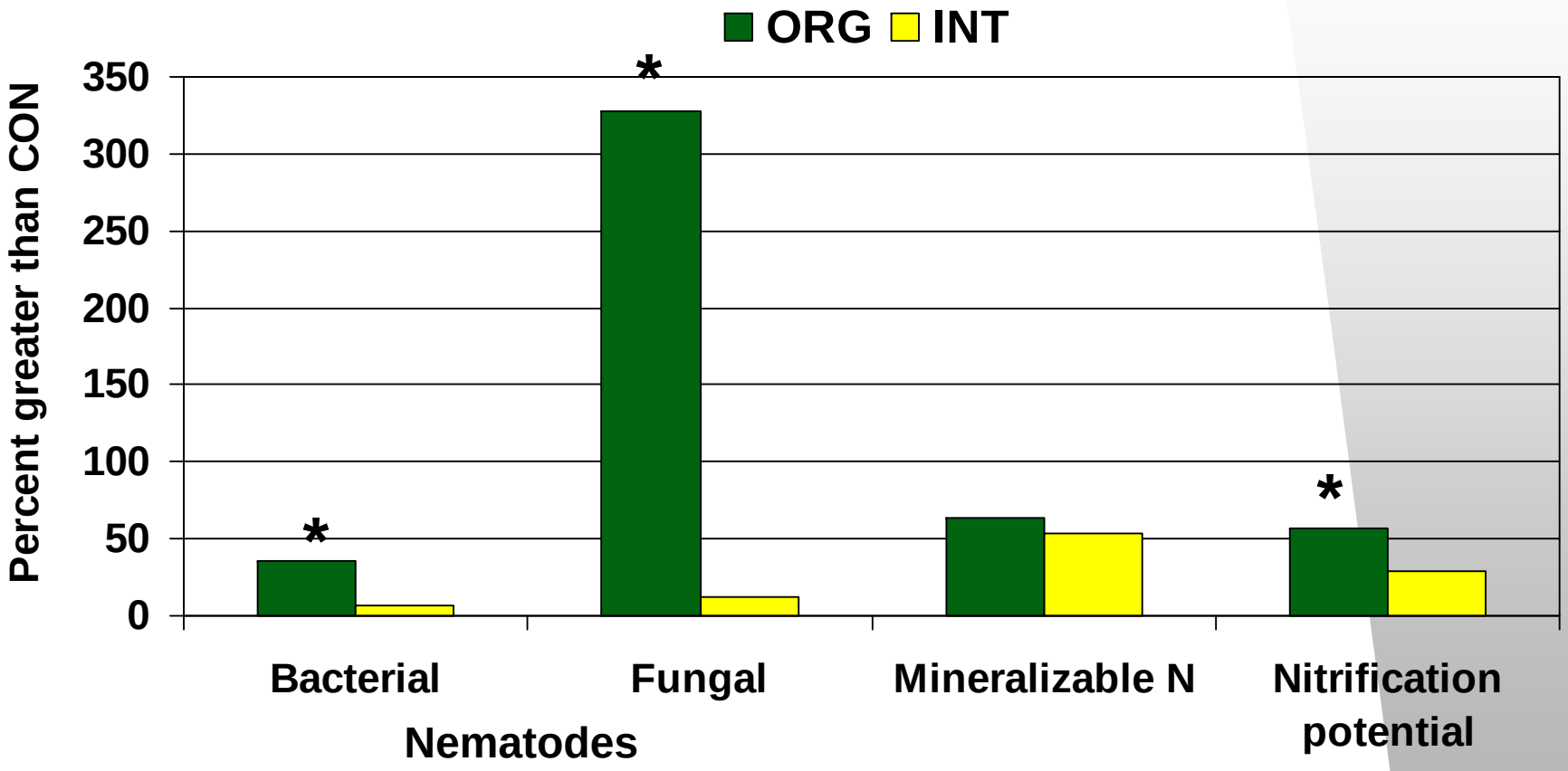
All higher in ORG

Nitrogen



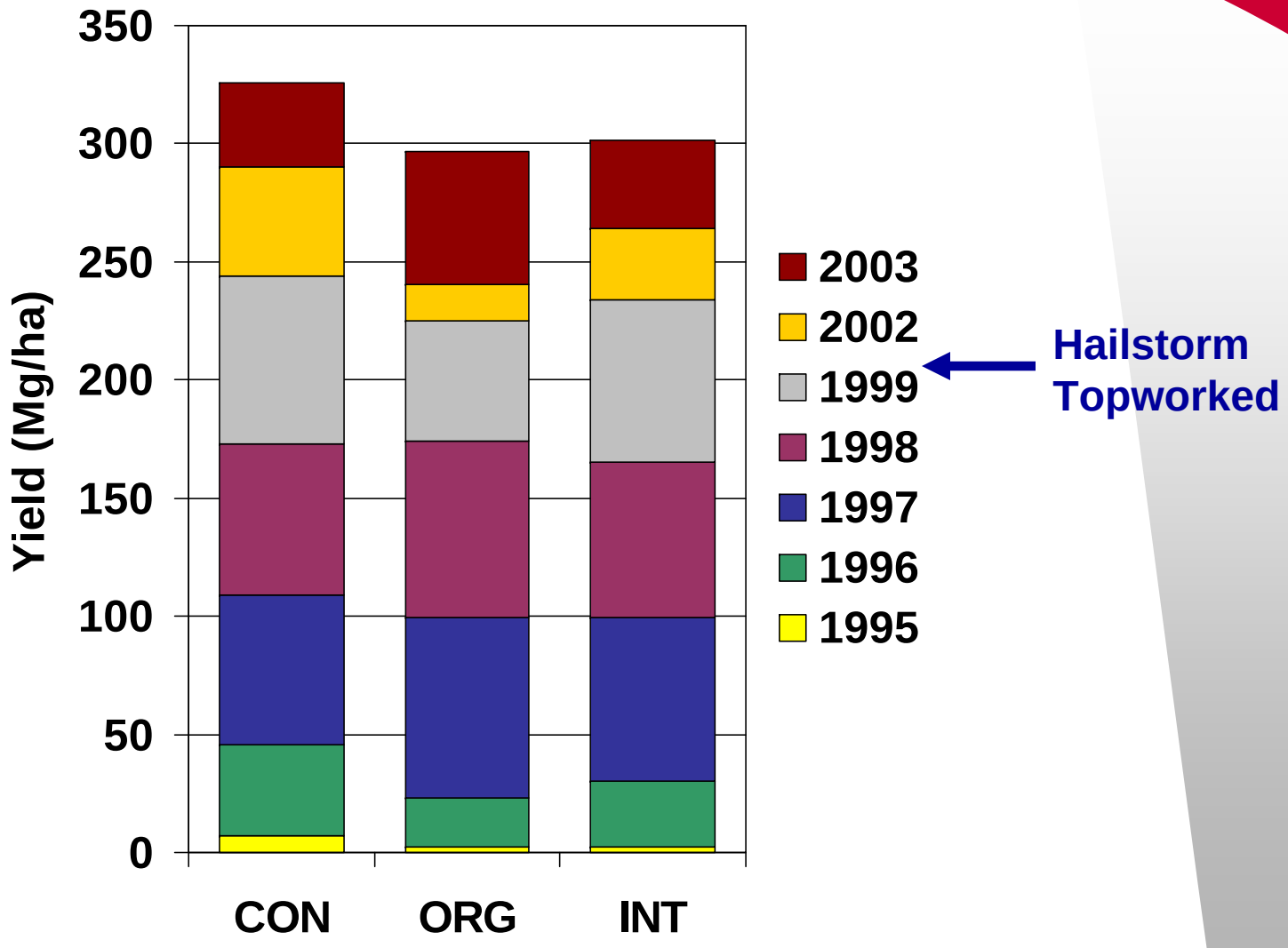
Soil food web

Topsoil



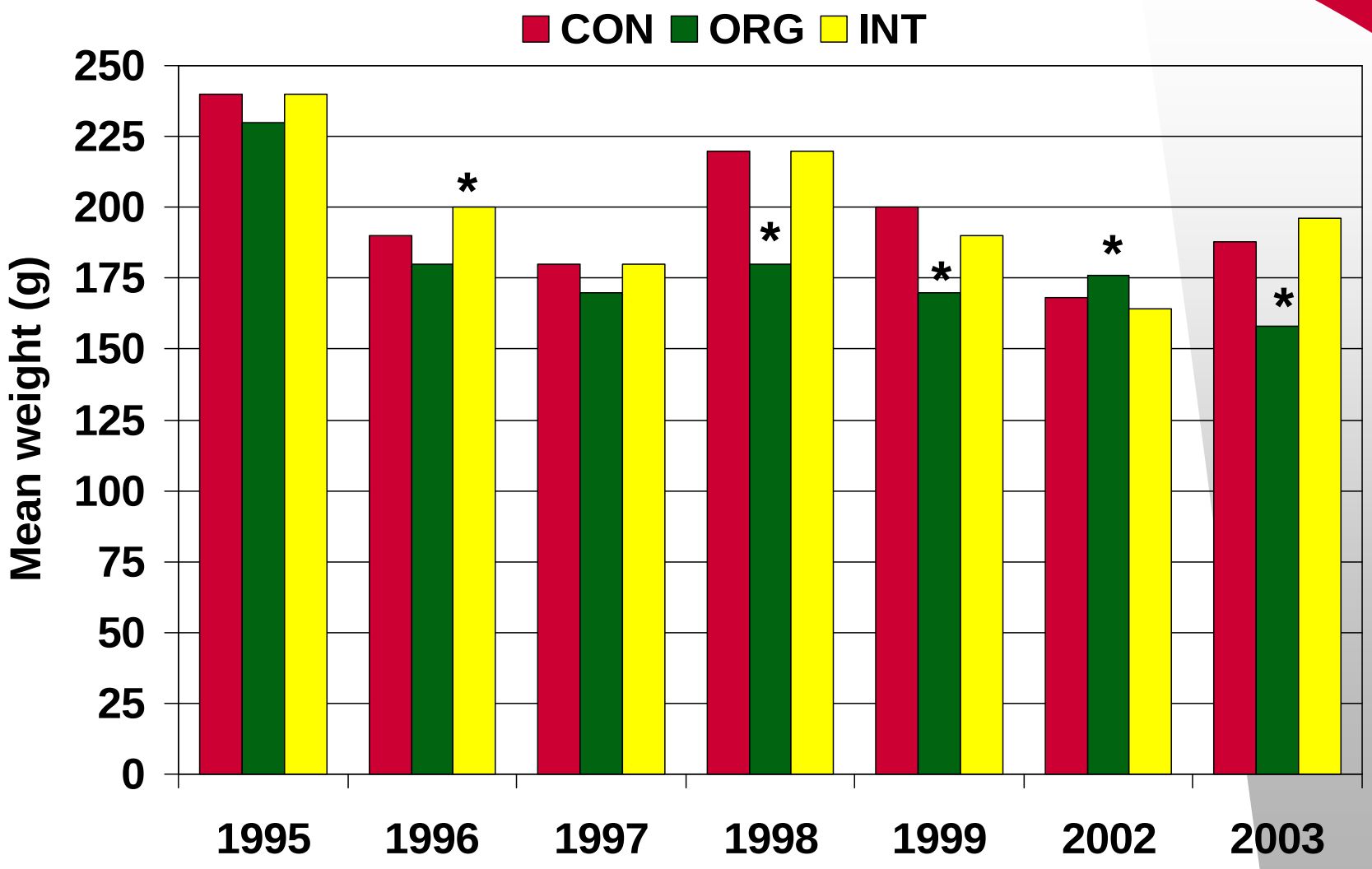
Glover *et al*, 2011

Yields

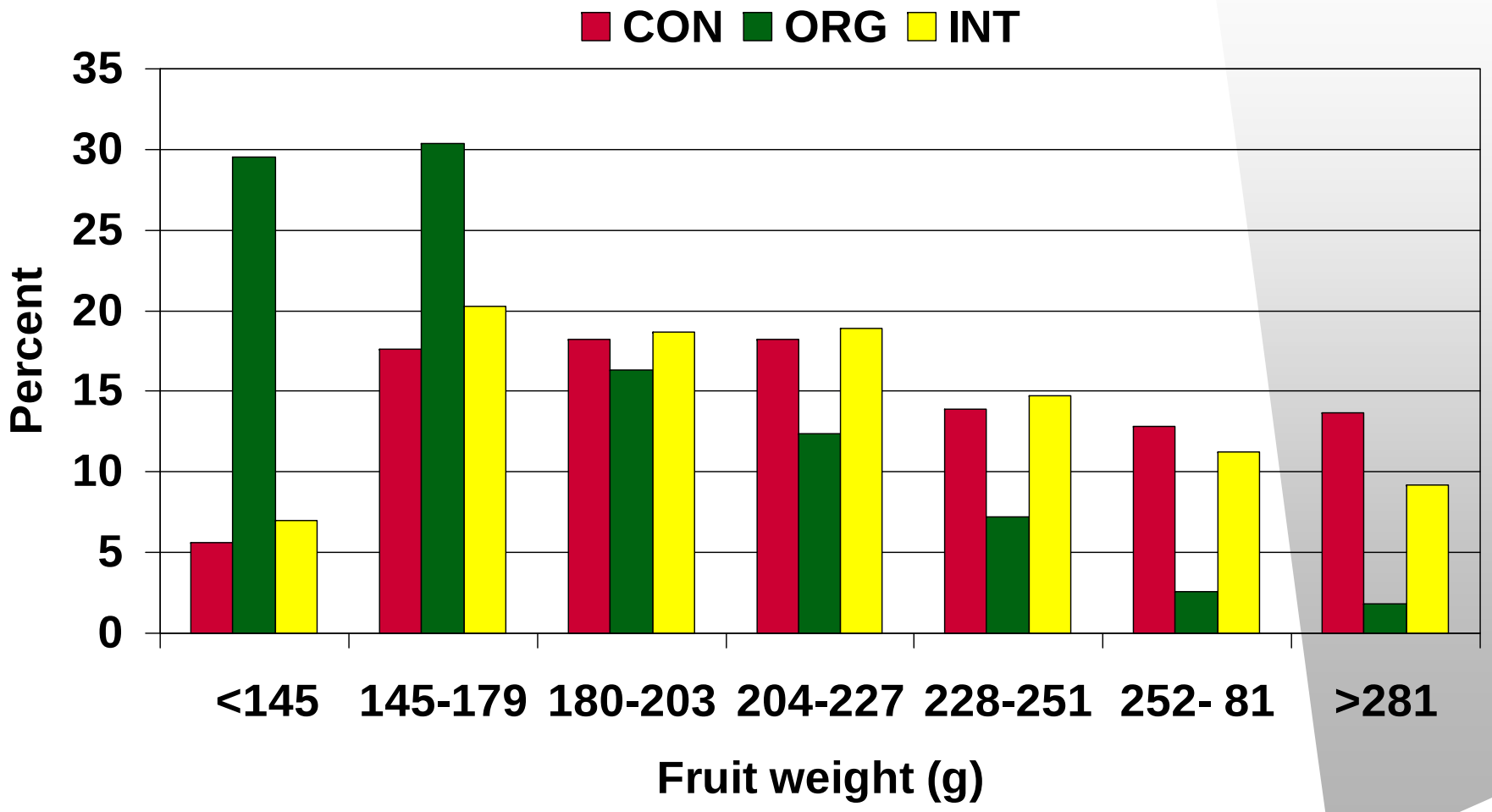

350
300
250
200
150
100
50
0
Yield (Mg/ha)
CON
ORG
INT
2003
2002
1999
1998
1997
1996
1995
Hailstorm
Topworked

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Fruit size

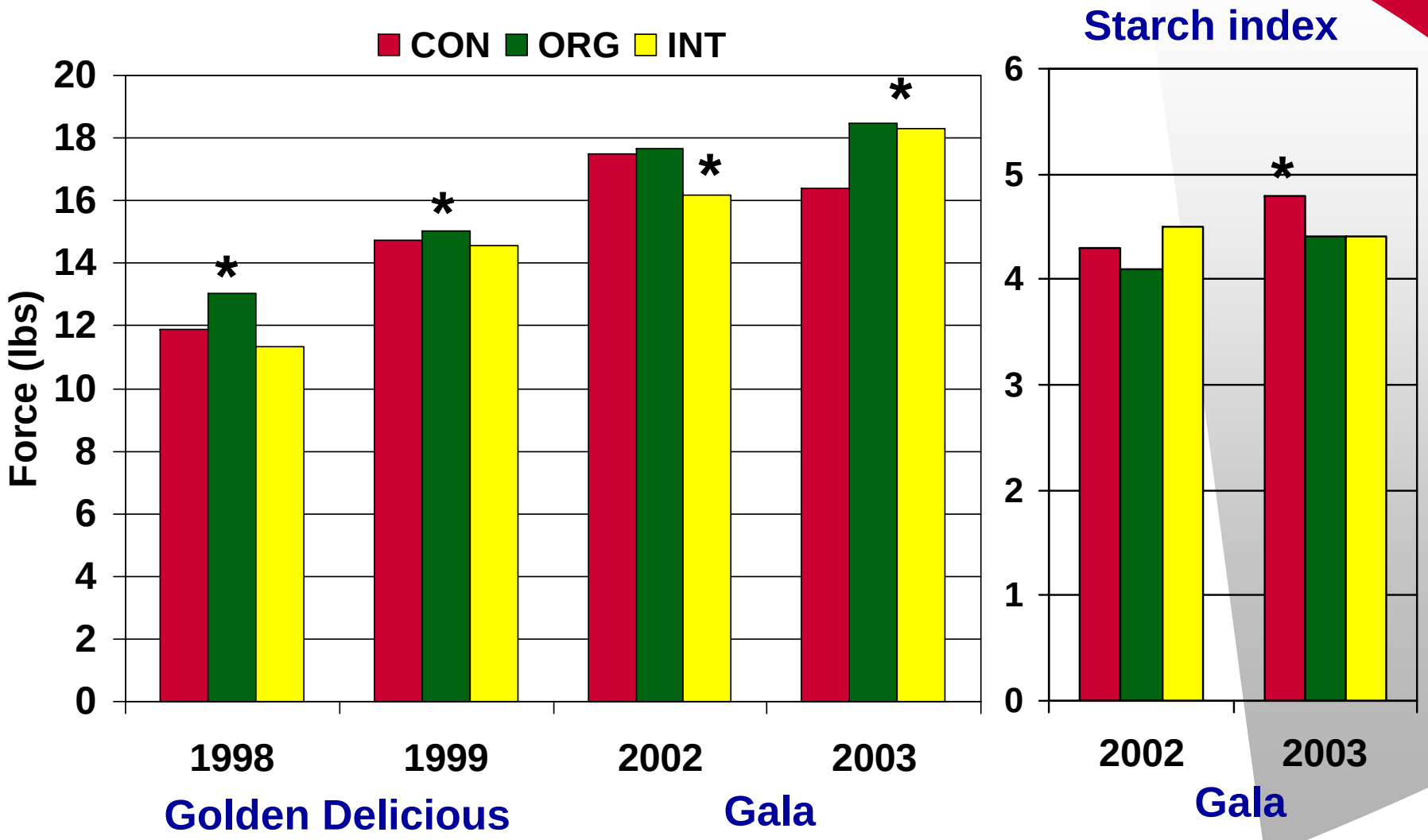


Fruit size distribution
(1998-99)



Fruit firmness

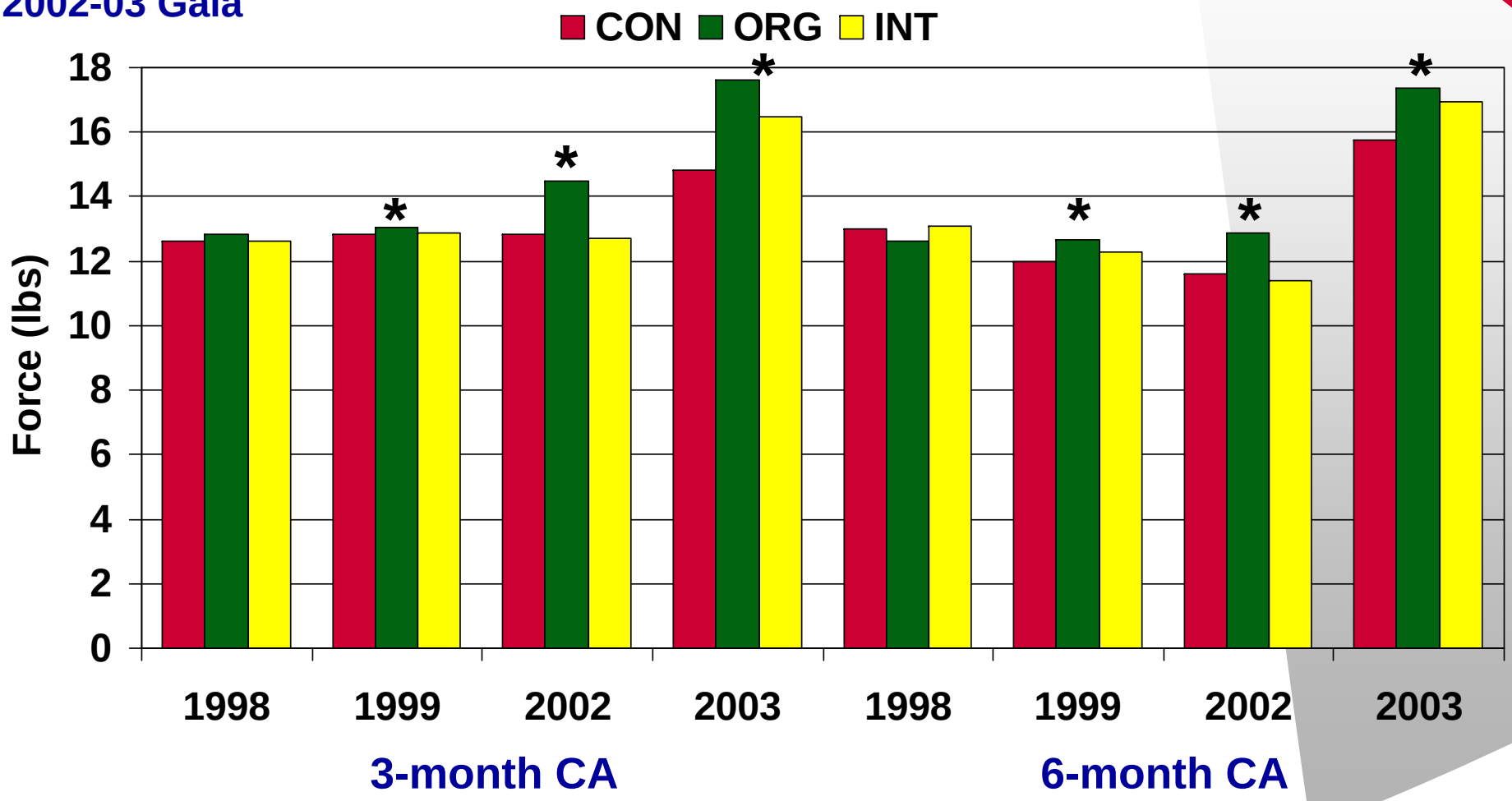
At harvest



Fruit firmness

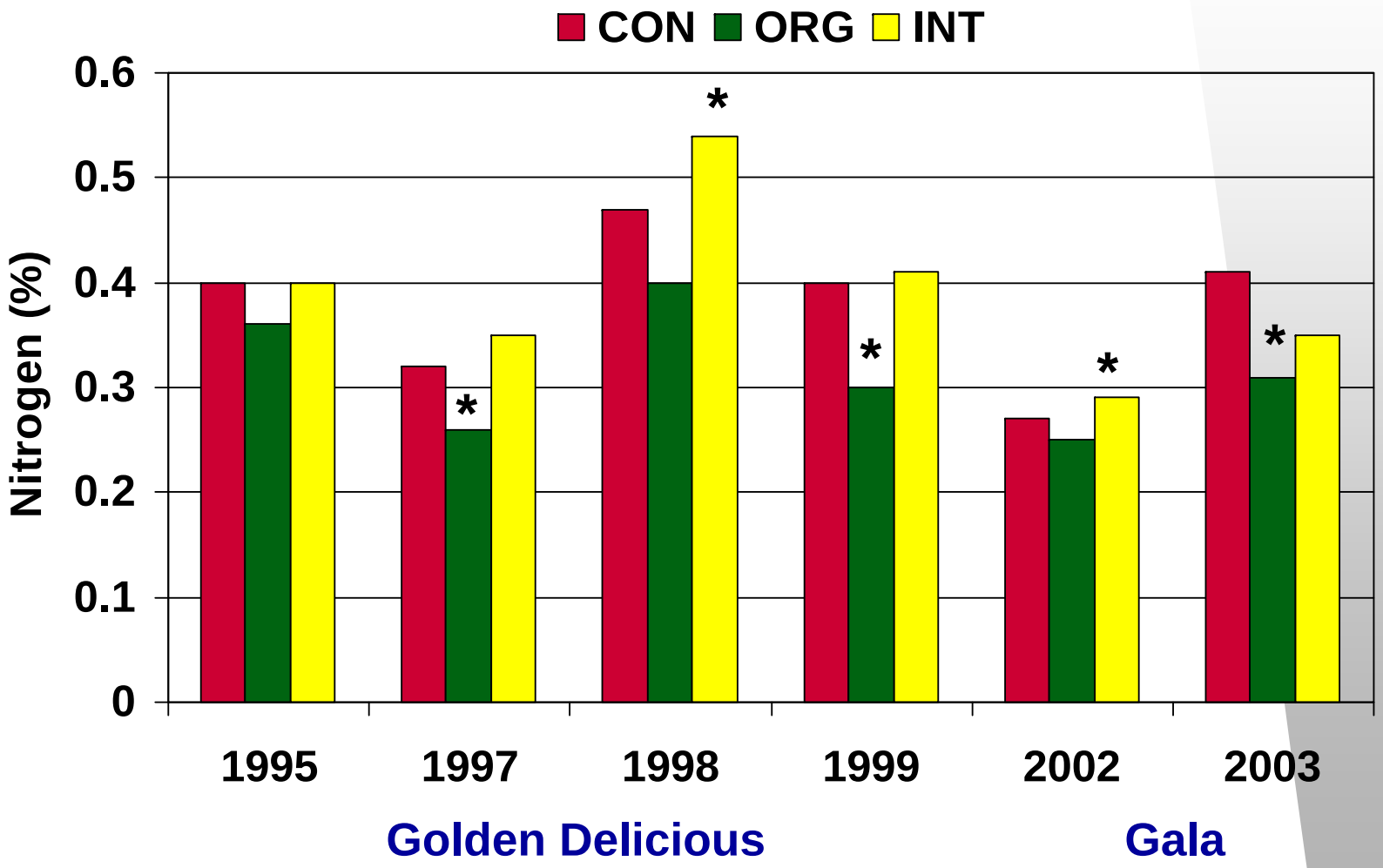
After CA storage

1998-99 Golden Delicious
2002-03 Gala



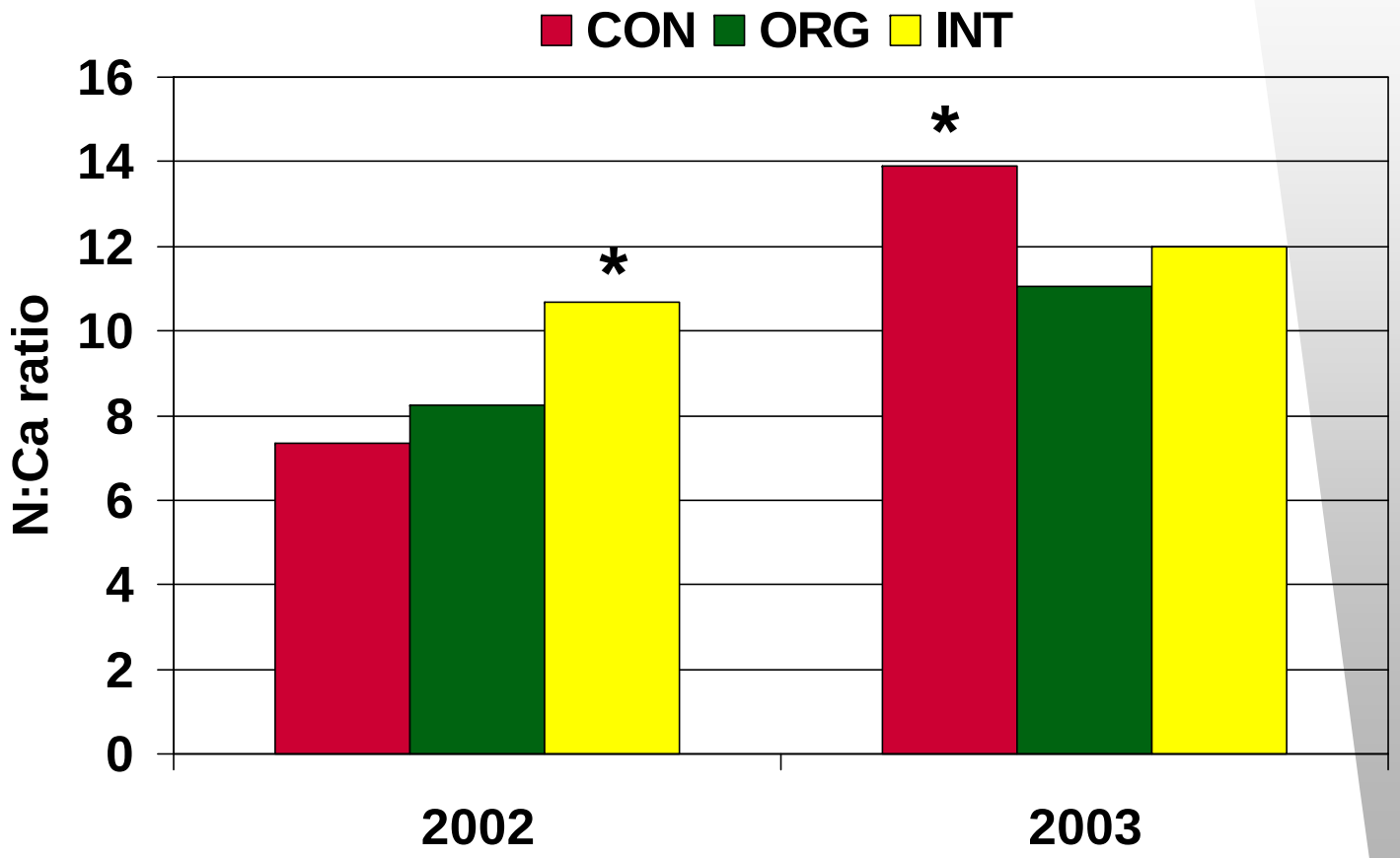
WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Fruit nitrogen



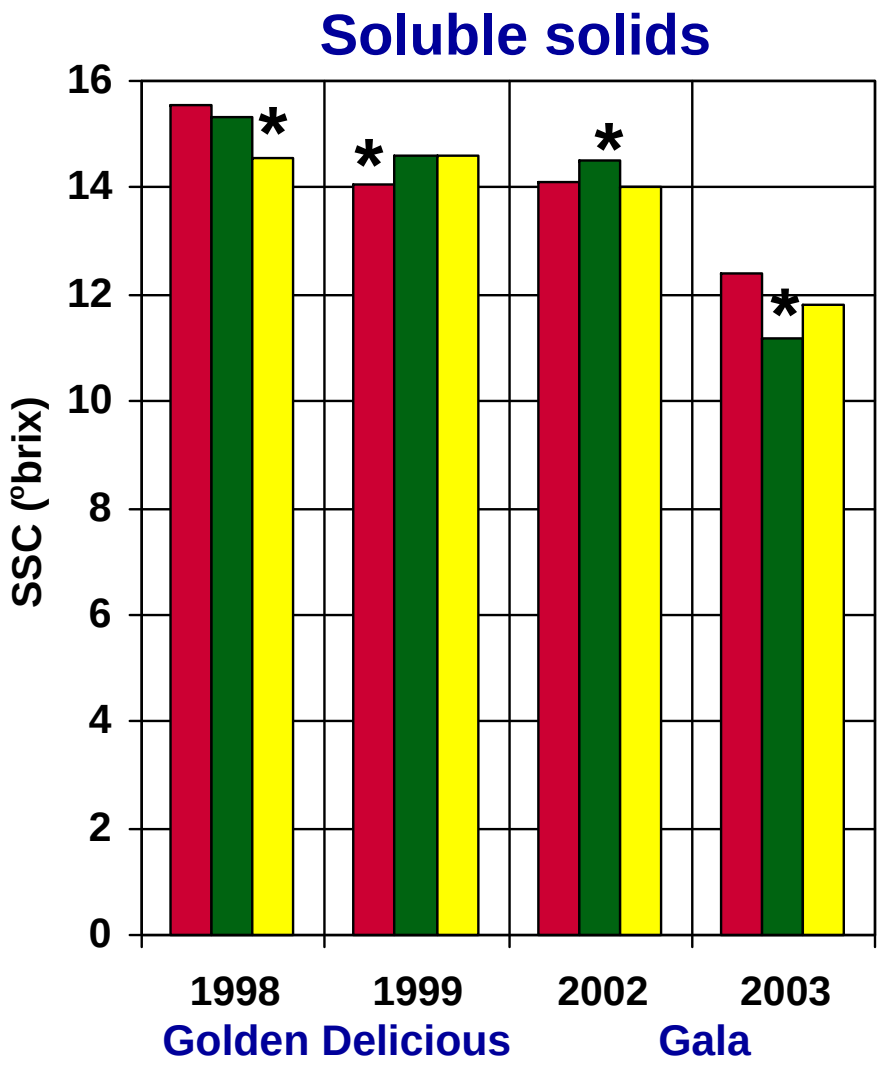
Fruit nitrogen:calcium ratio

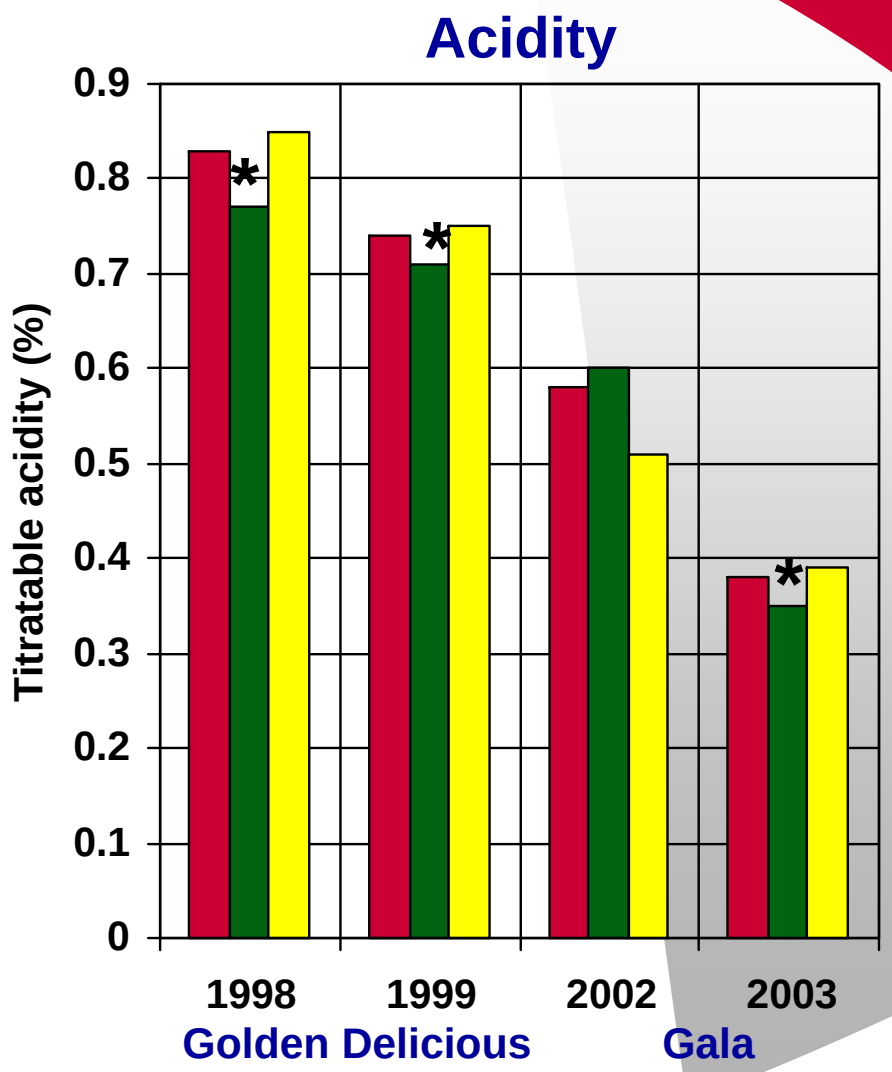
Gala



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

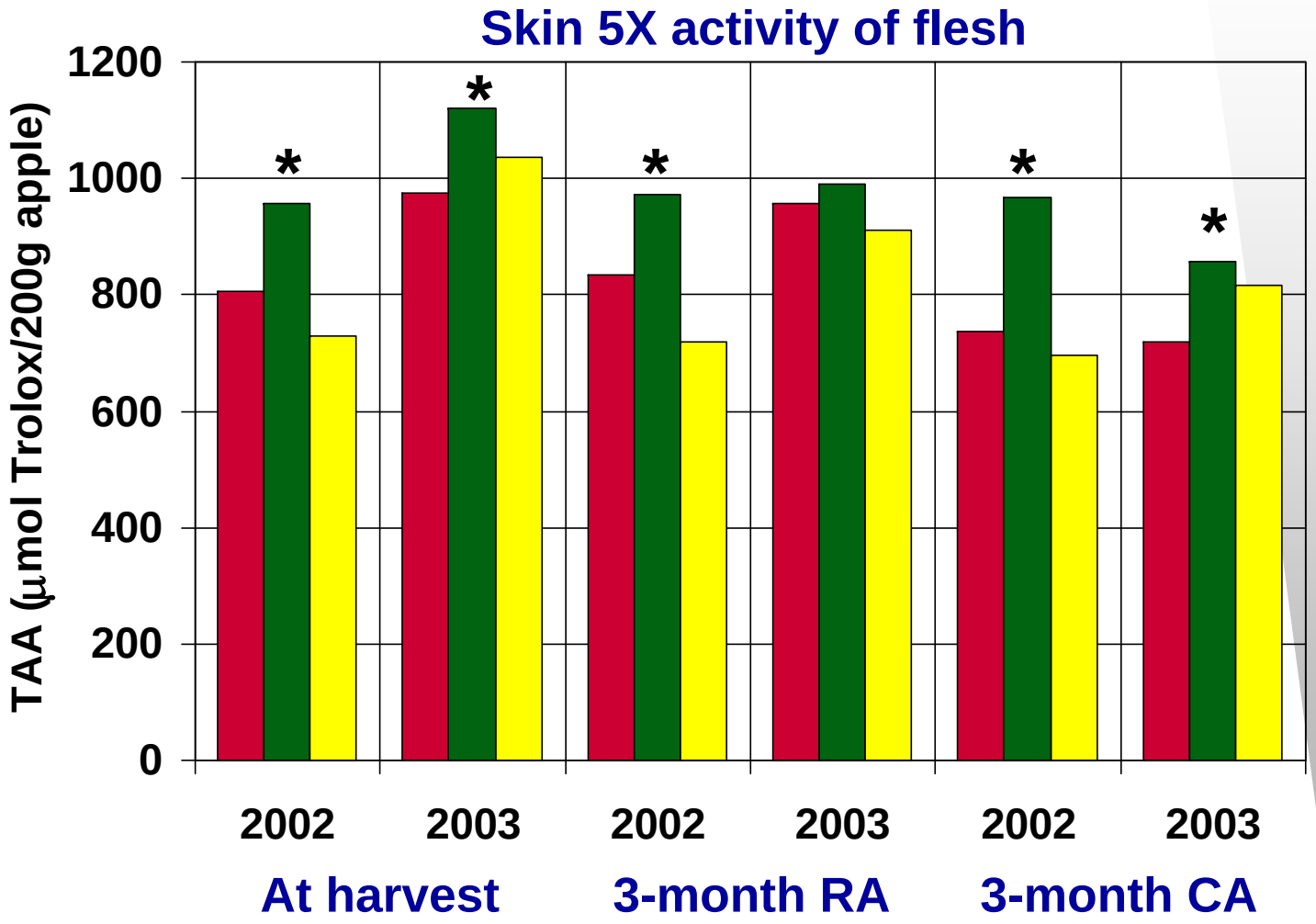
Soluble solids & acidity





Antioxidant activity

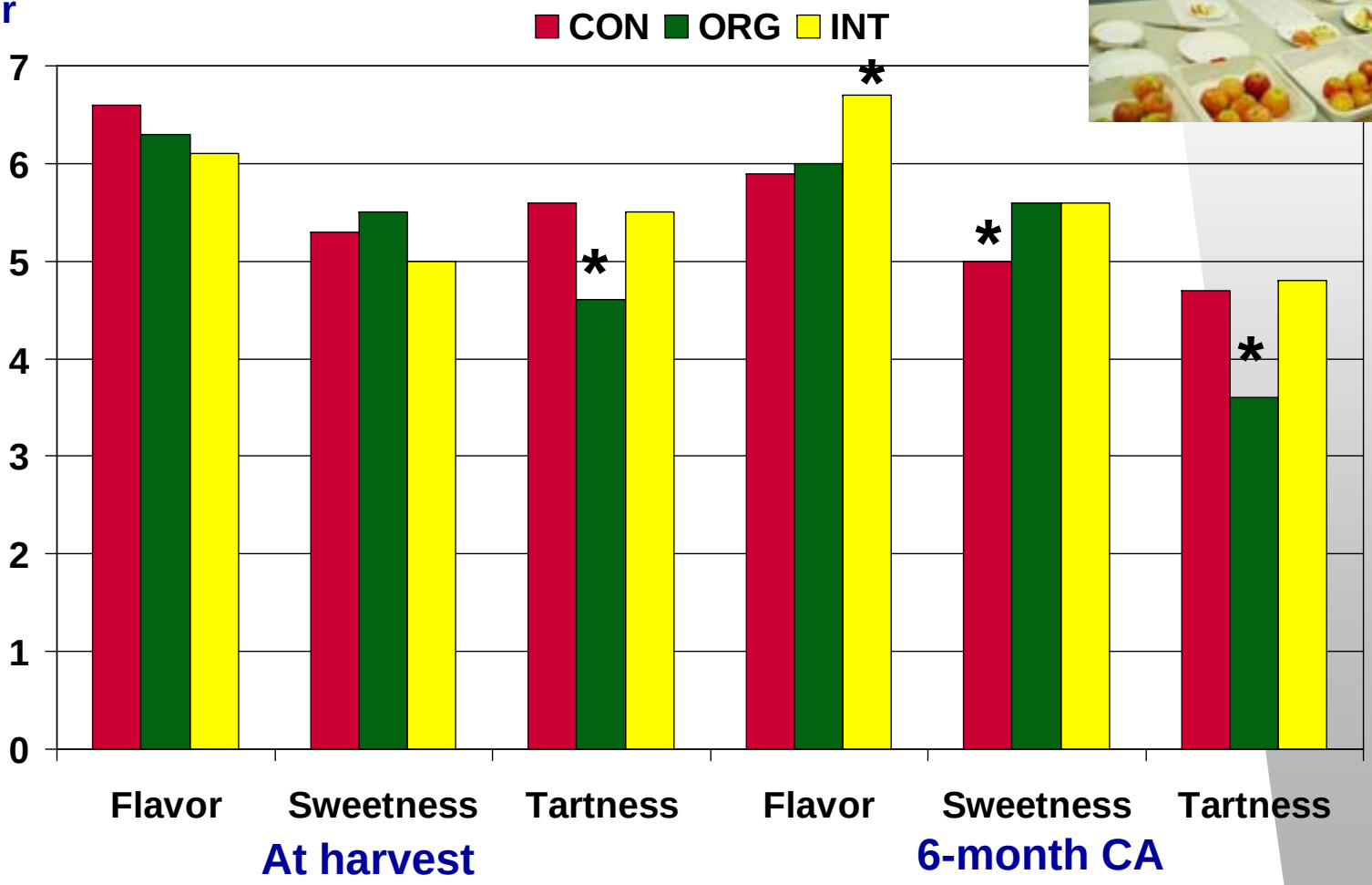
Gala



Consumer preference

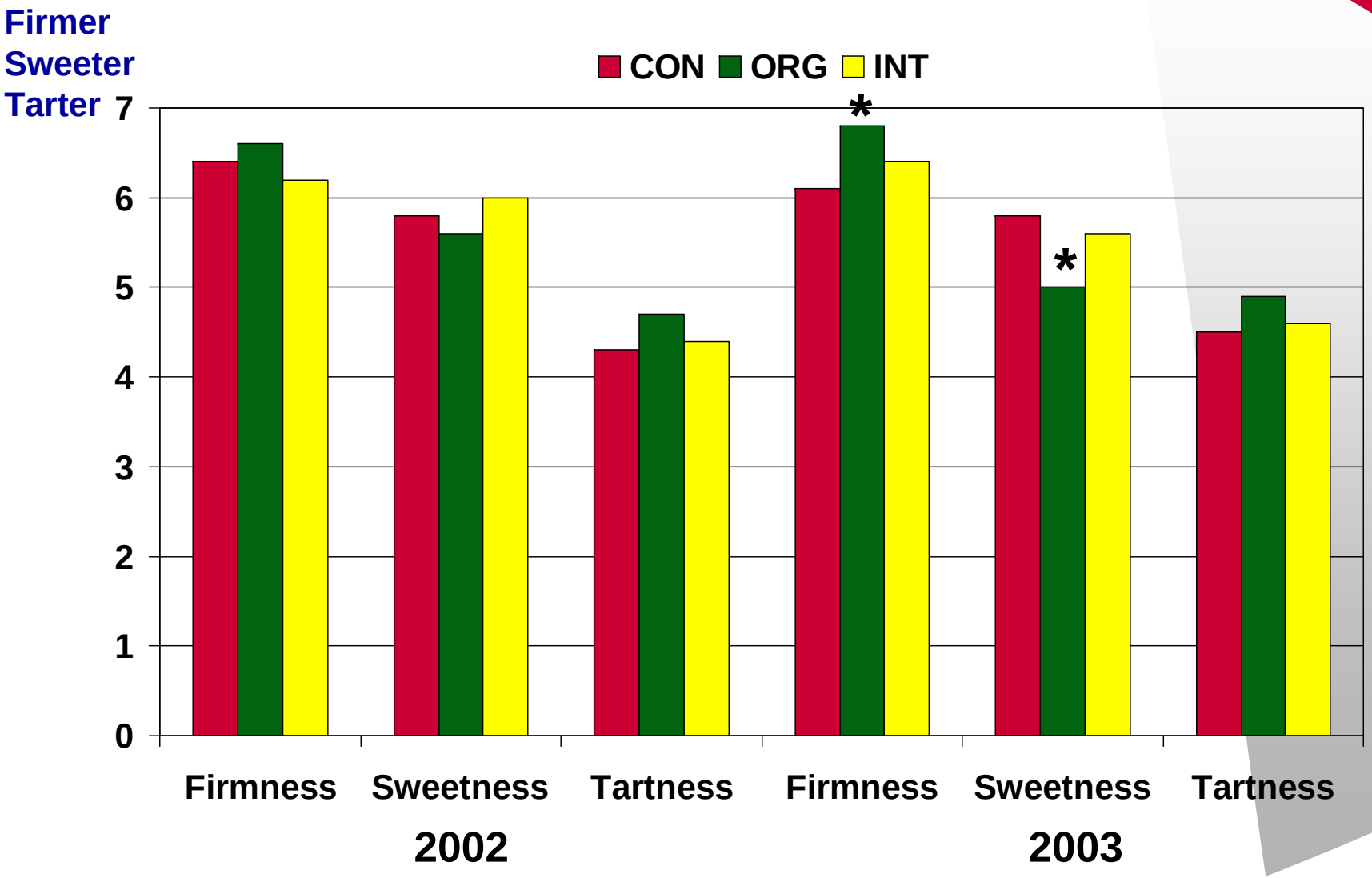
Golden Delicious

More flavor
Sweeter
Tarter



Consumer preference

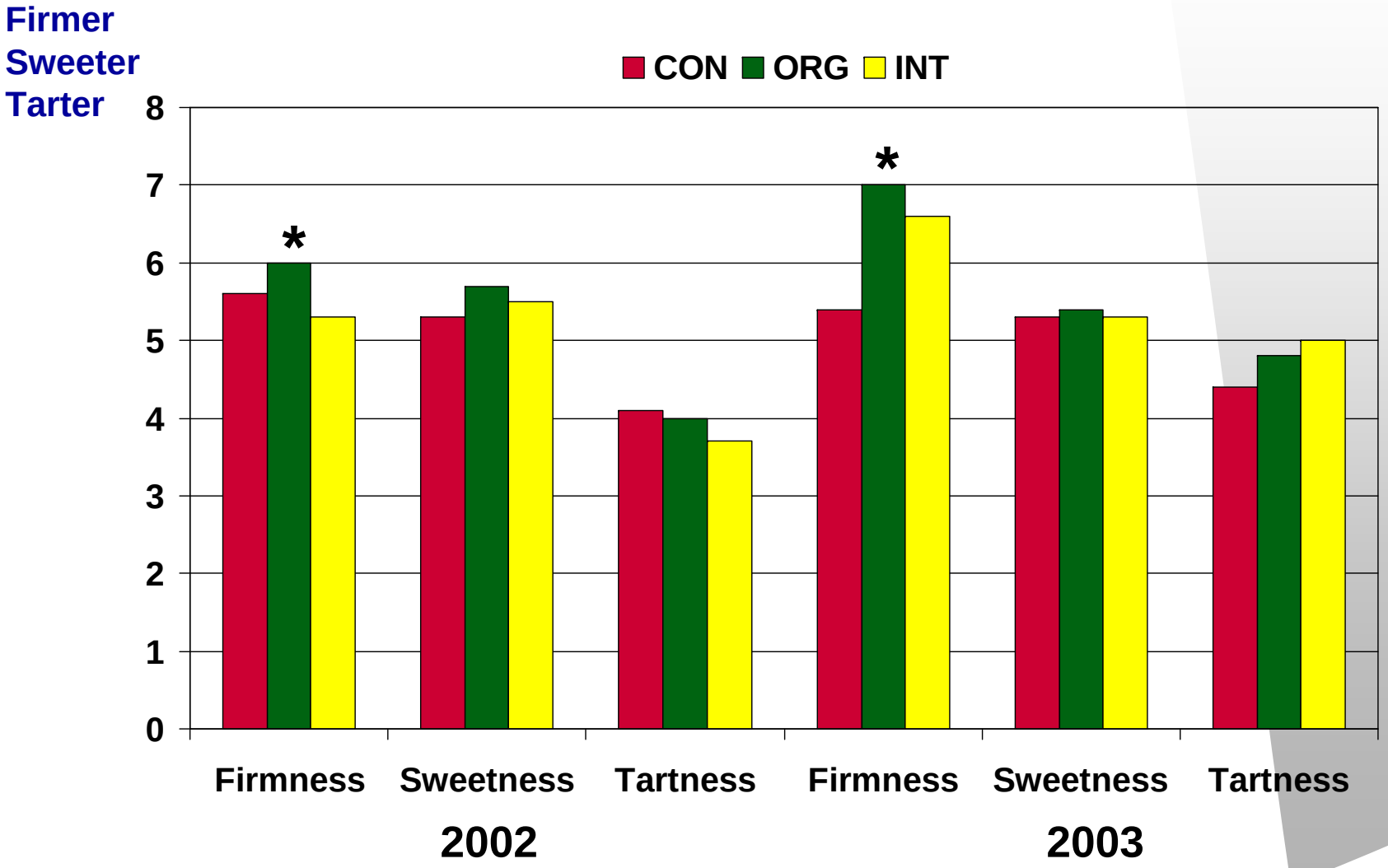
Gala at harvest



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Consumer preference

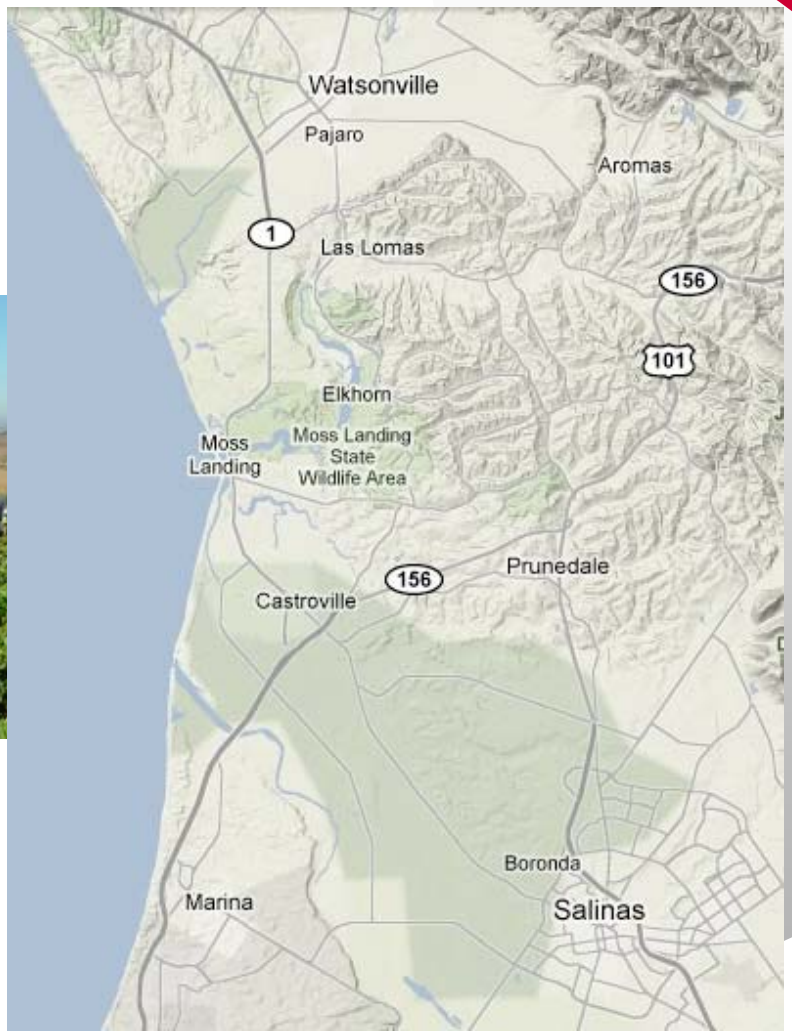
Gala after 3-month CA storage



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

California strawberry study

- 13 matched pairs commercial organic & conventional fields
- matched soil, topography, microclimate
- 3 cultivars
- 2004-05



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

OPEN ACCESS Freely available online

PLoS one

Fruit and Soil Quality of Organic and Conventional Strawberry Agroecosystems

John P. Reganold[1]*, Preston K. Andrews[2], Jennifer R. Reeve[3], Lynne Carpenter-Boggs[4], Christopher W. Schadt[5], J. Richard Alldredge[6], Carolyn F. Ross[7], Neal M. Davies[8], Jizhong Zhou[9]

Soil inputs
2004-05

	Conventional	Organic
Fumigants	methyl bromide chloropicrin	none
Fertilizers	compost (4.6-5.5 tons/A) NH_4-SO_4 Ca thiosulfate Ca-NH_4-SO_4 humic acid kelp extract K-NO_3 Na borate urea	compost (8.4-10.2 tons/A) gypsum humic acid kelp extract fish emulsion bloodmeal feathermeal greensand sulfate of potash
Herbicides	Paraquat, Devrinol	none

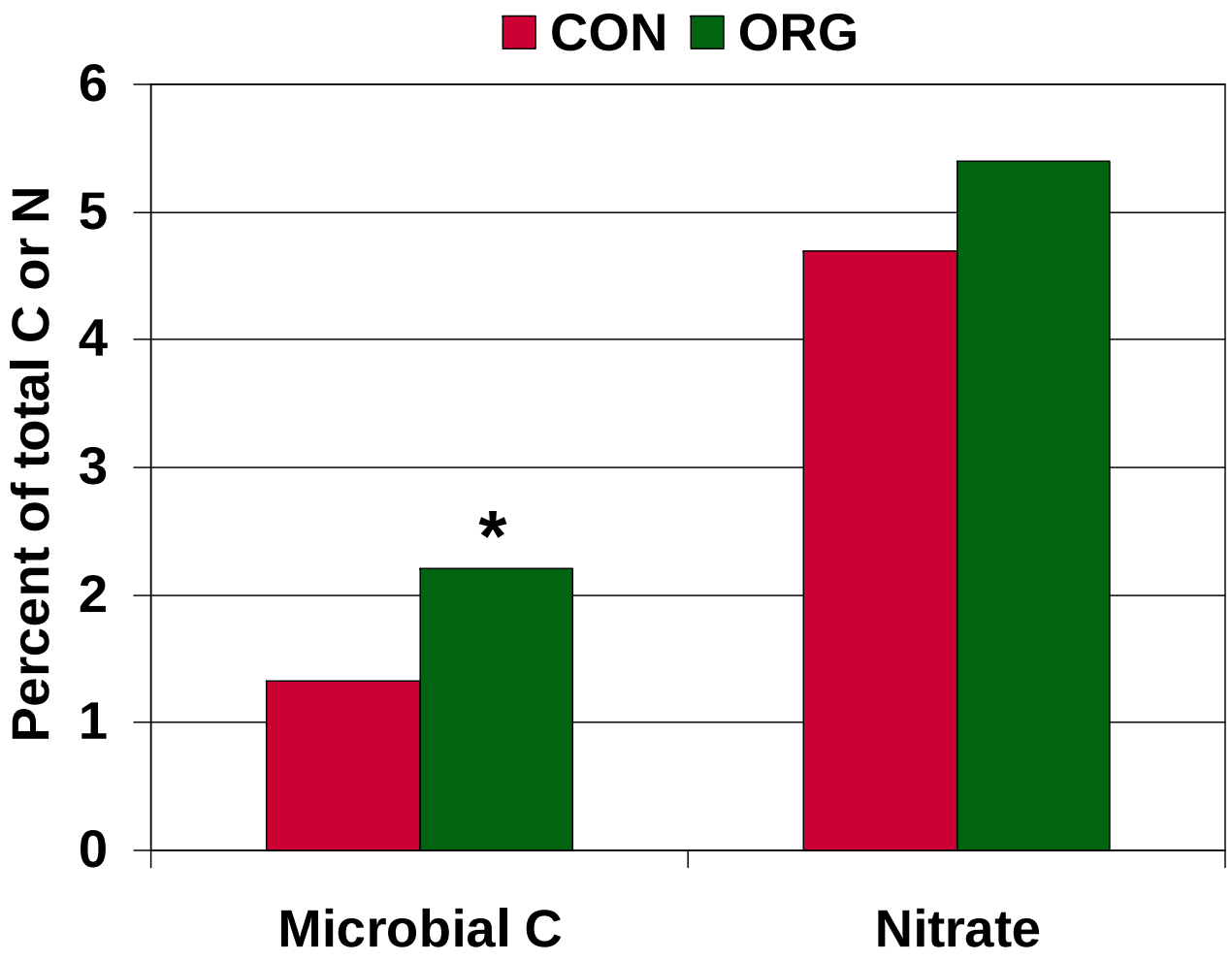
Soil biological properties

2004-05

Biological property	Conventional	Organic
Total C (g C/kg soil)	8.25	10.04 *
Total N (g N/kg soil)	0.666	0.867 **
Organic matter (mg/kg soil)	1.46	1.84 *
Microbial biomass (μg CO_2-C/g soil)	96	249 ***
Readily mineralizable C (μg CO_2/g)	14.1	17.7 **
Basal respiration (μg CO_2/g)	0.35	0.47 *
Mycorrhizae (per mm root length)	104	122

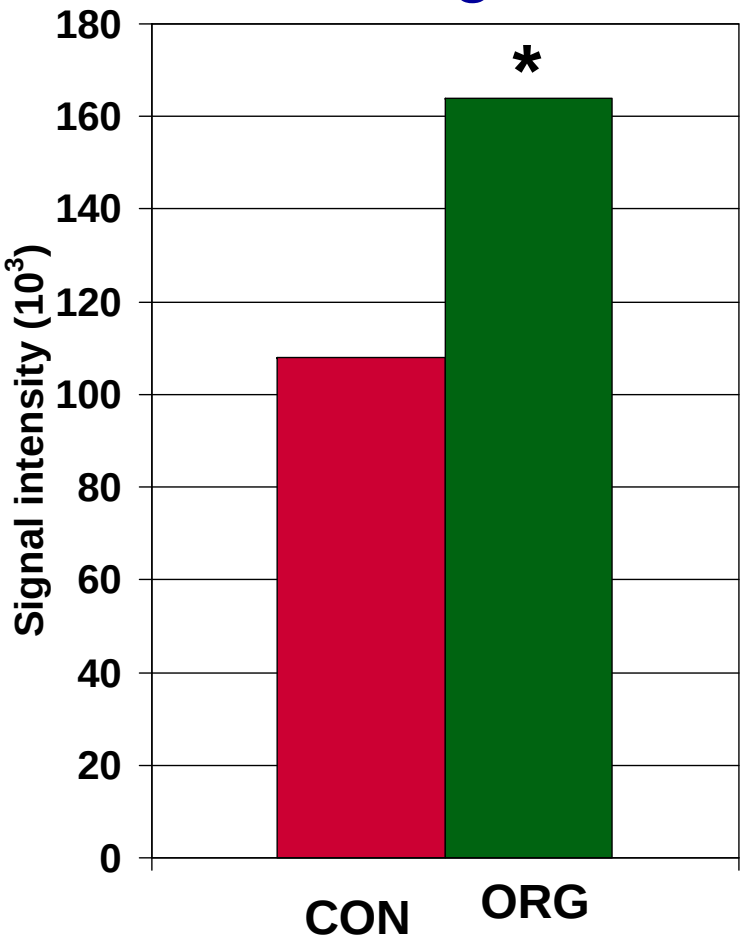
*p<0.05, **p<0.01, ***p<0.001

Soil carbon & nitrate

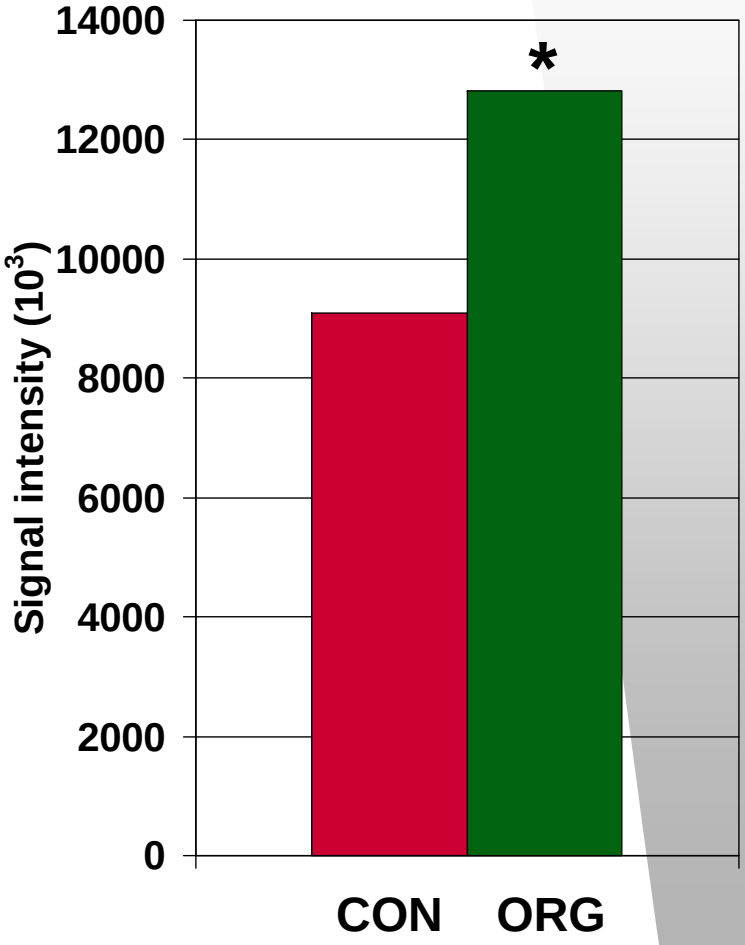


Soil gene activity

Fungi

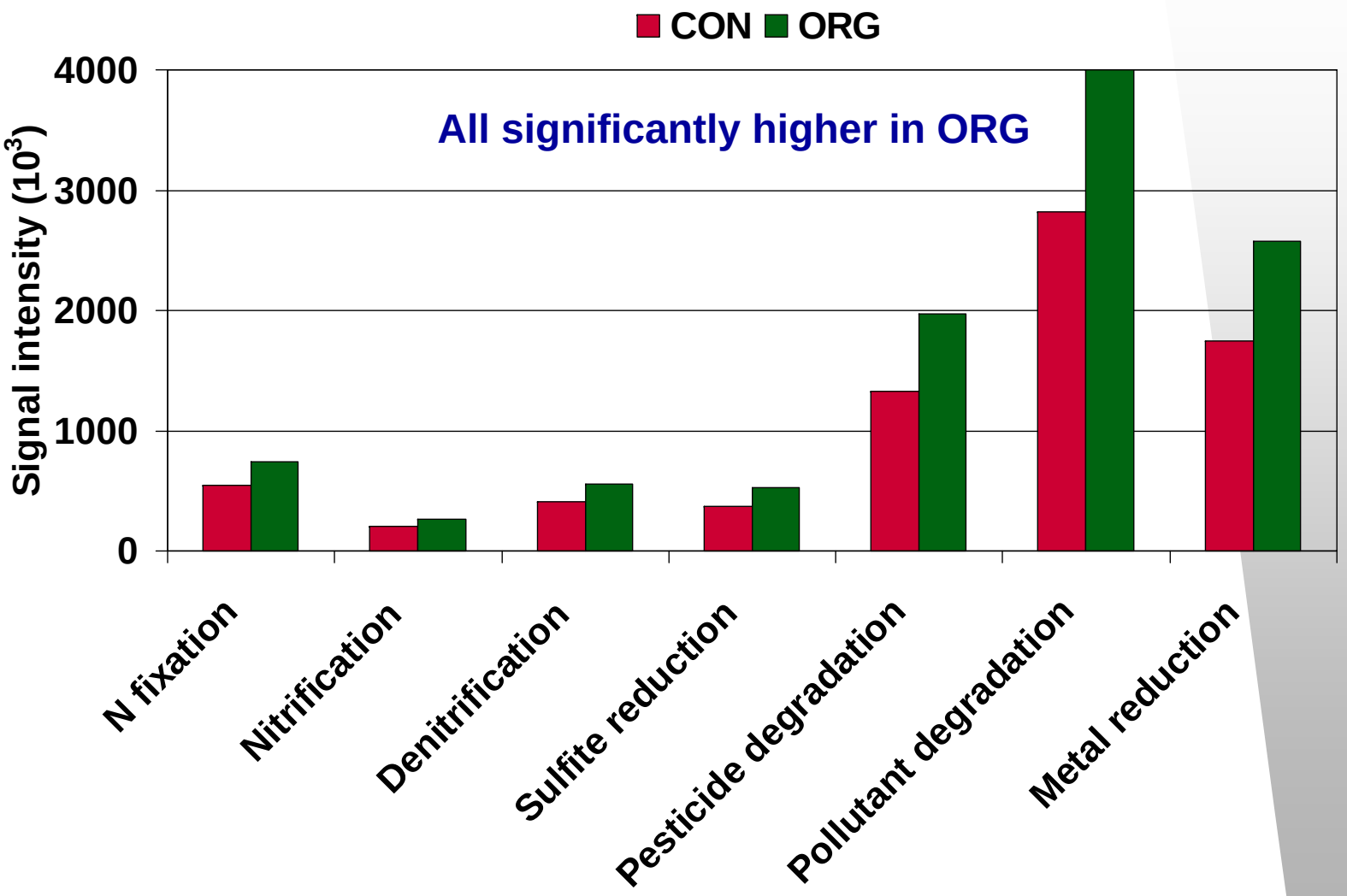


Prokaryotes

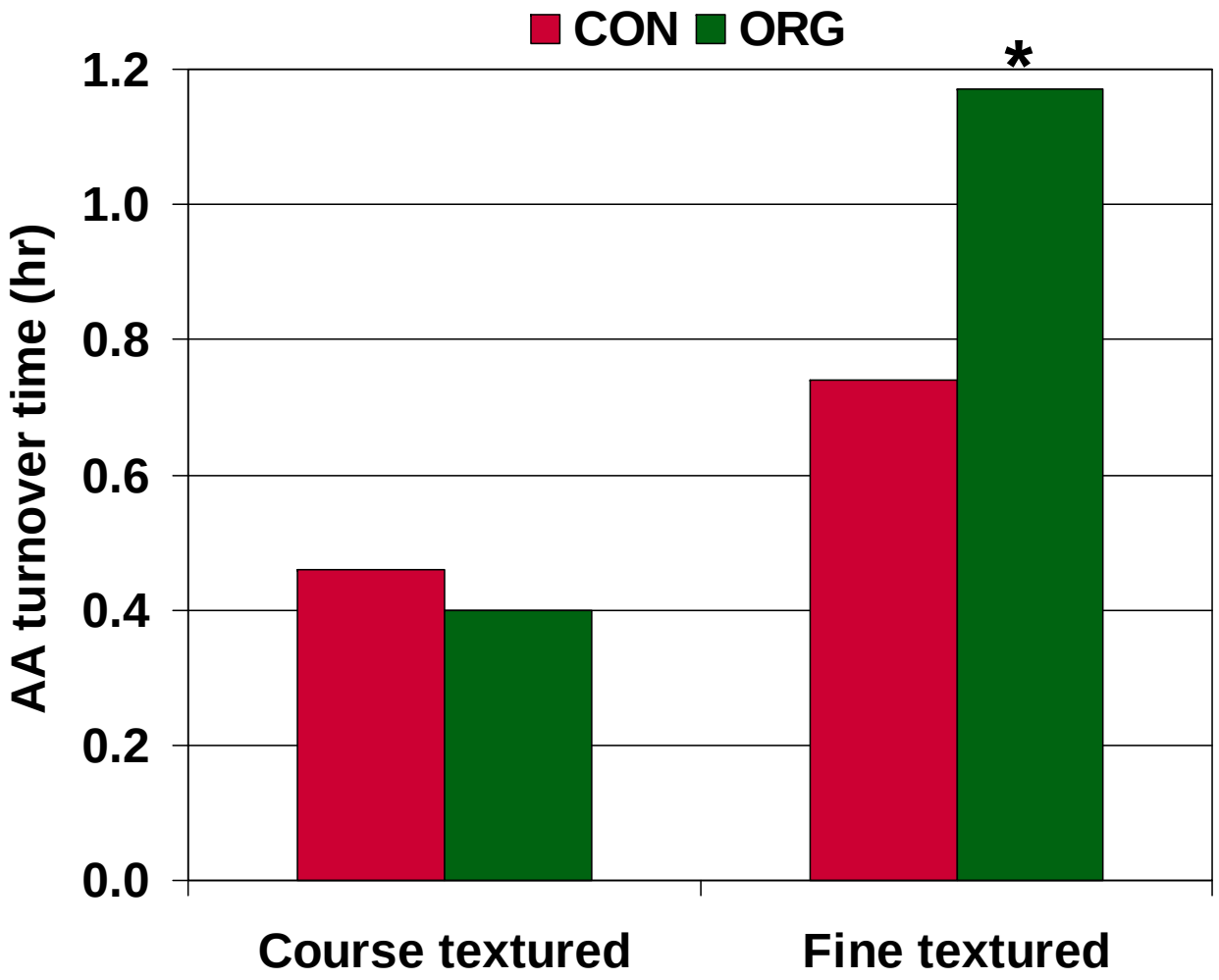


WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Soil gene activity



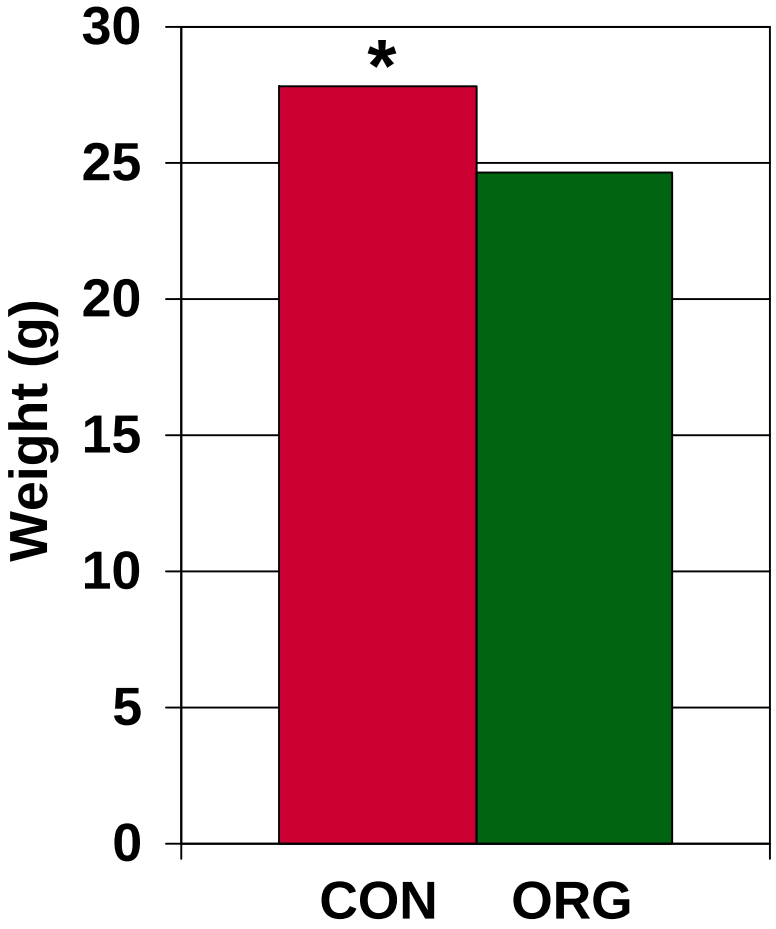
Amino acid turnover

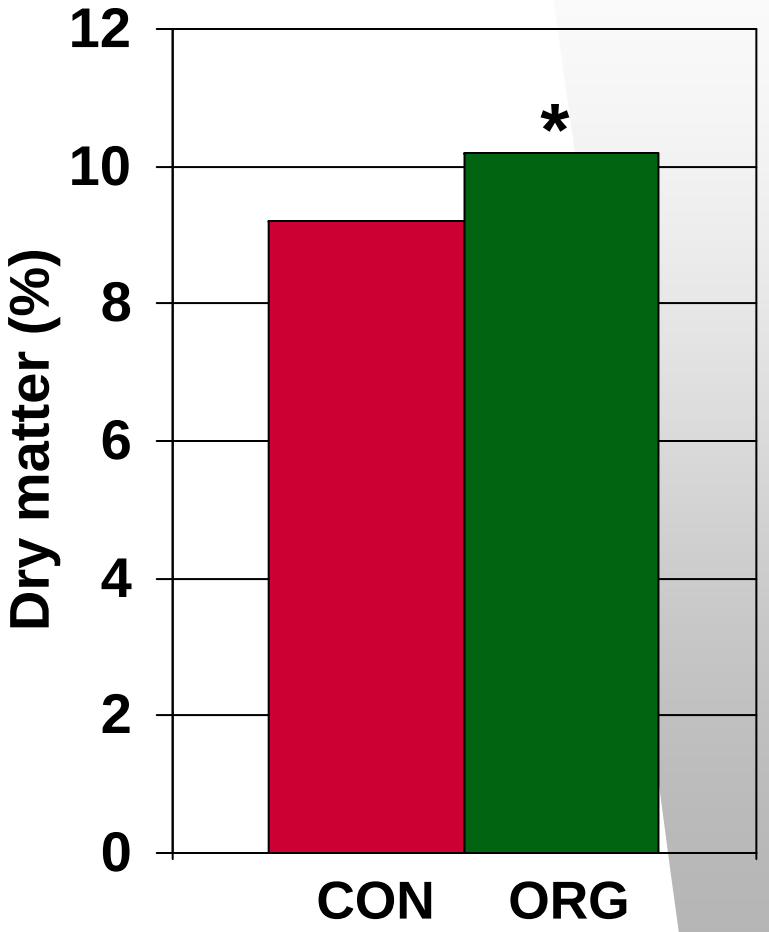


Reeve *et al*, *Soil Biol & Biochem* (2008)

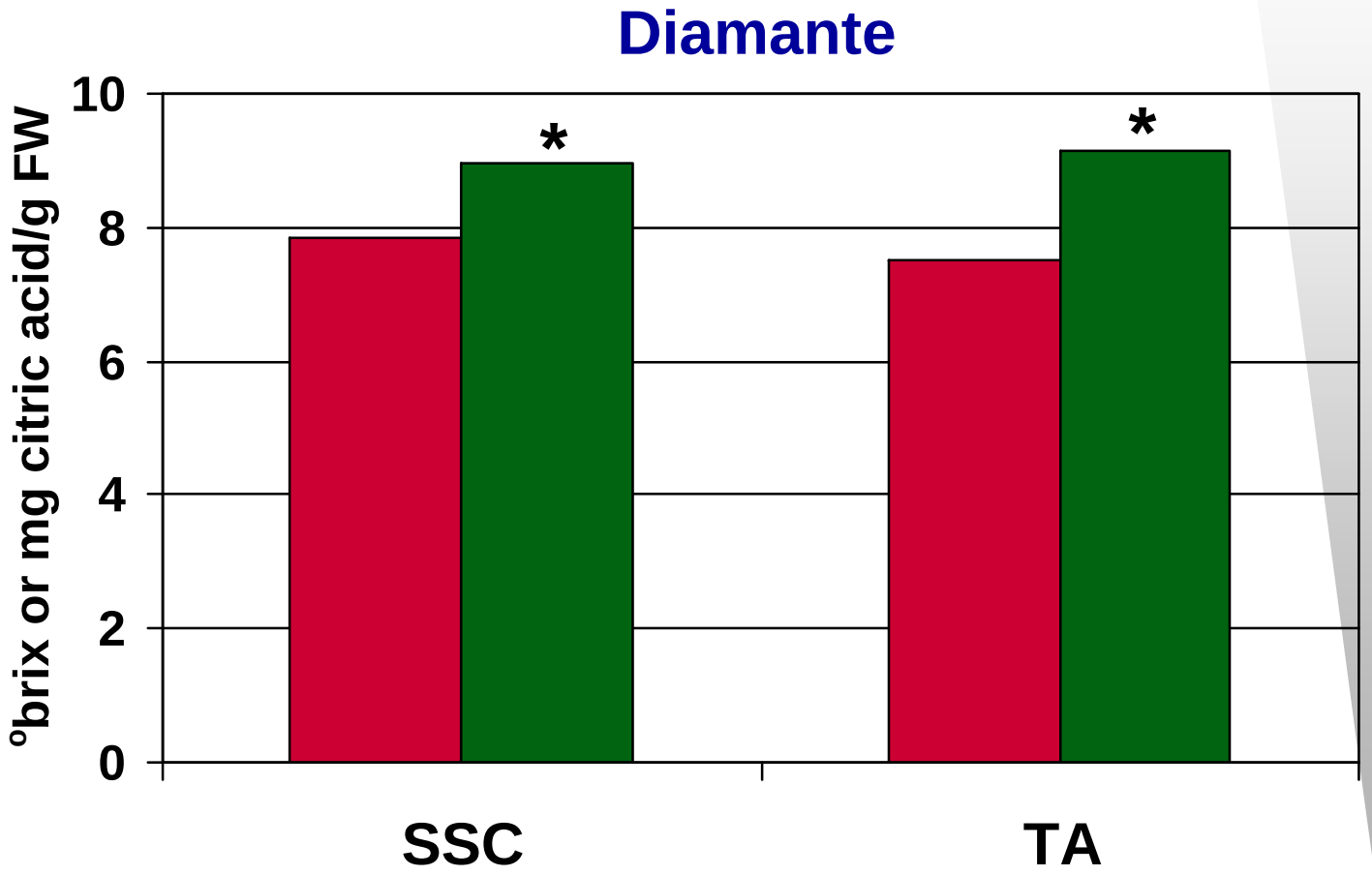
WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Fruit size & dry matter



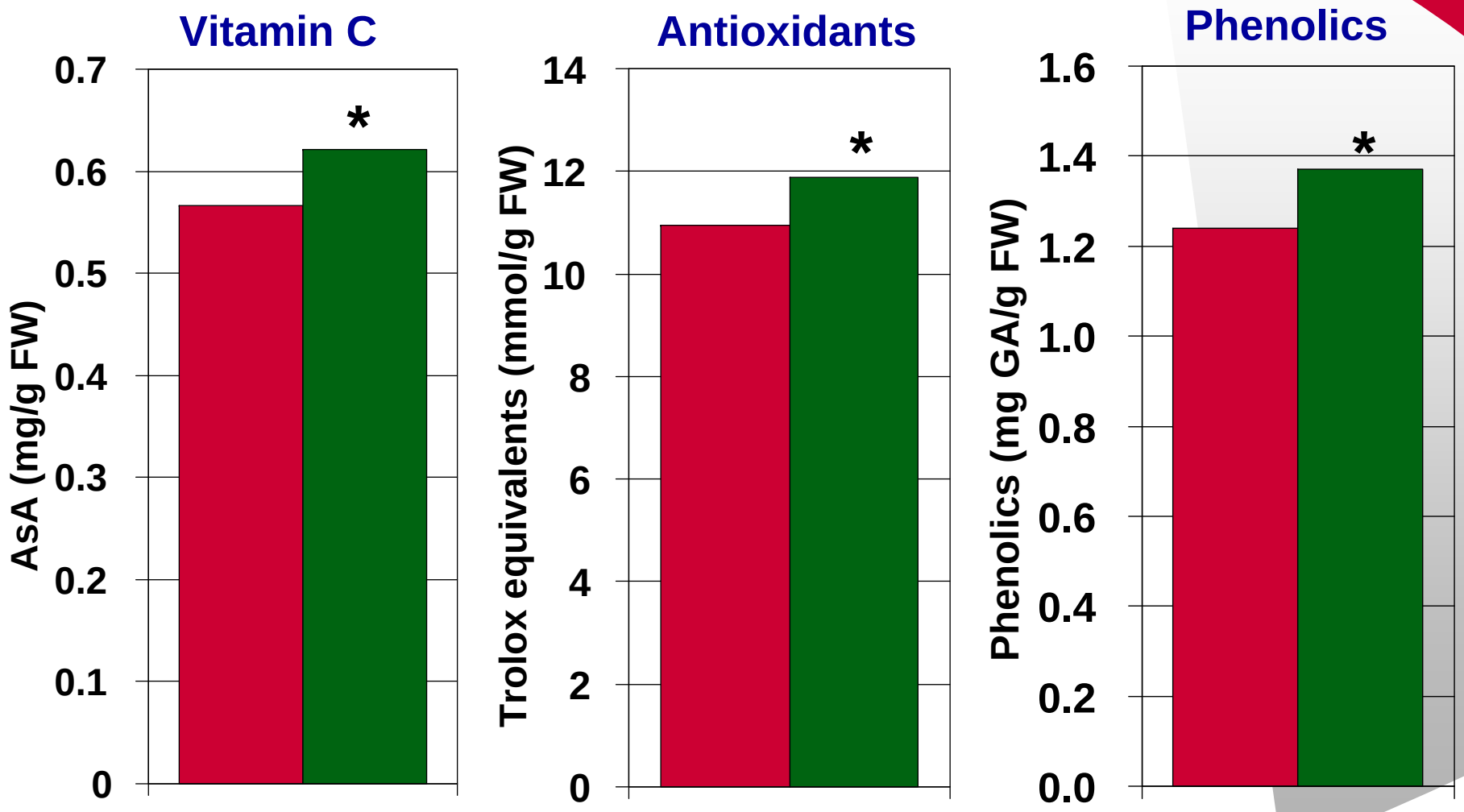


Soluble solids & titratable acidity

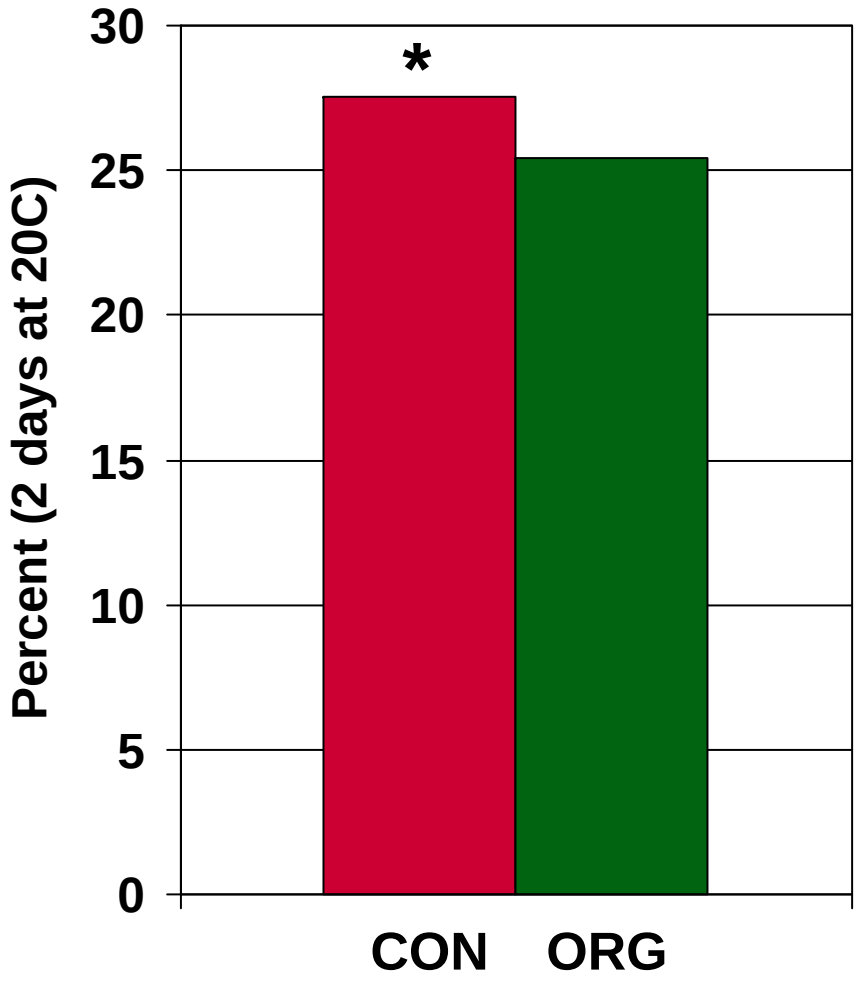


WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

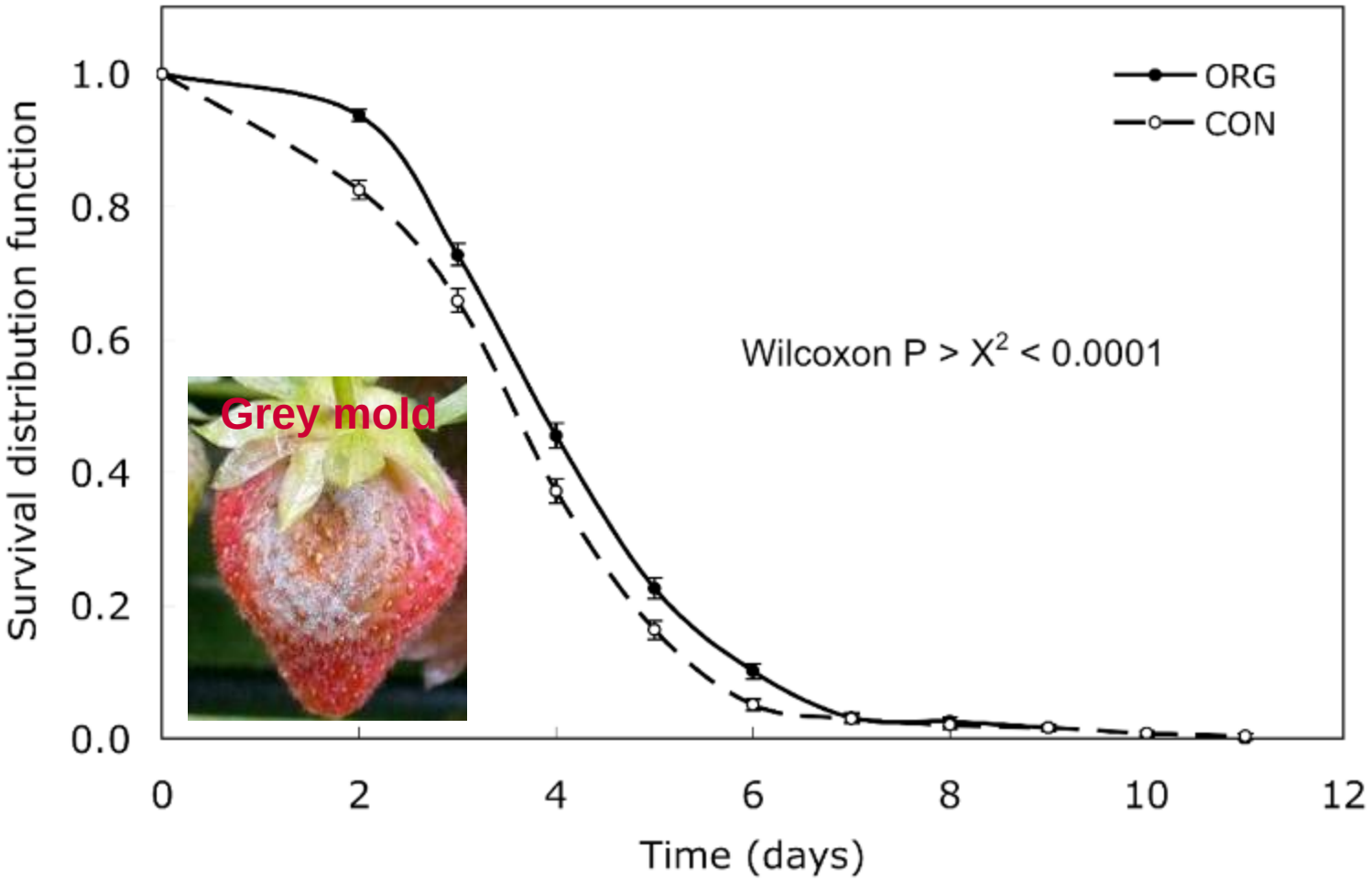
Phytonutrients



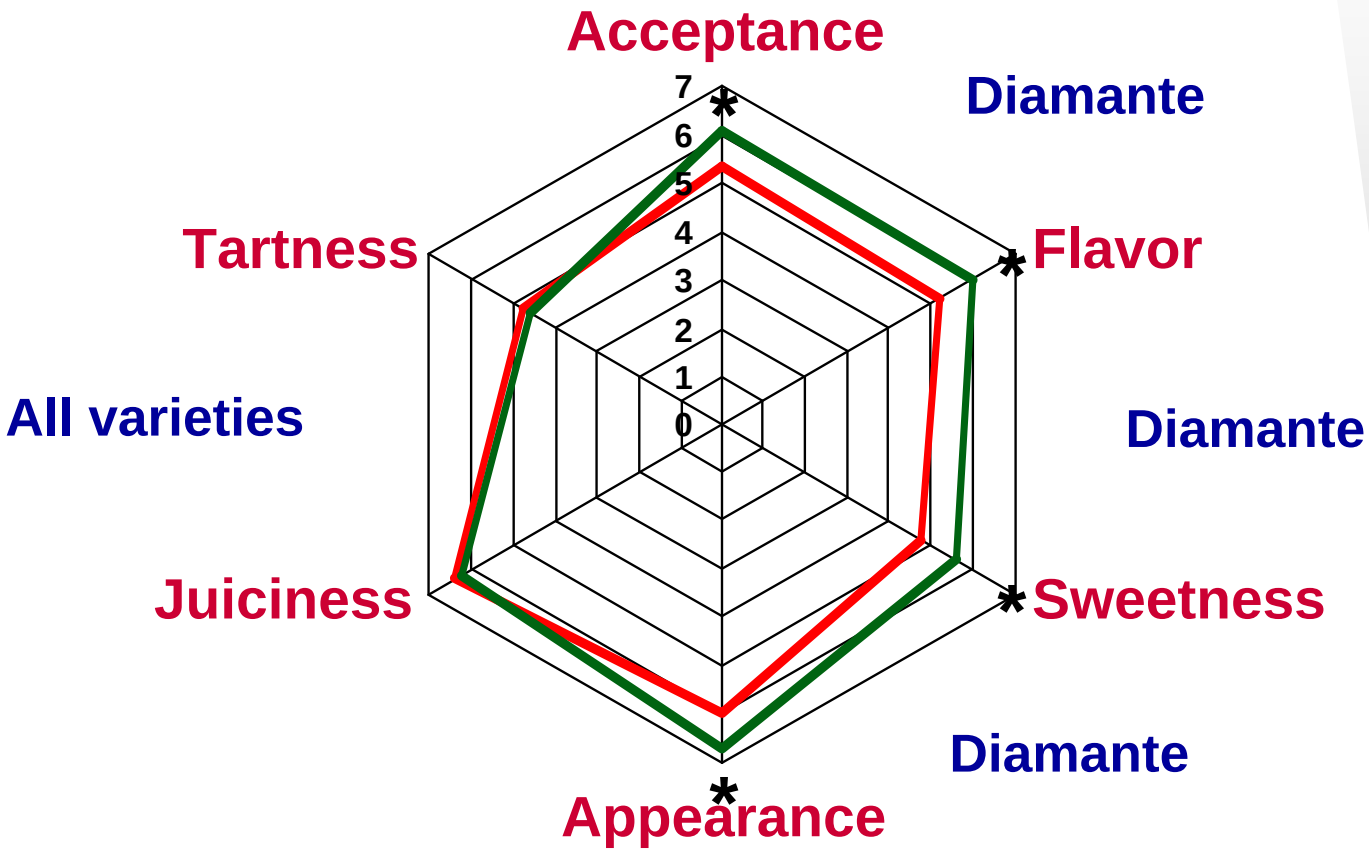
Fruit weight loss



Fungal rot

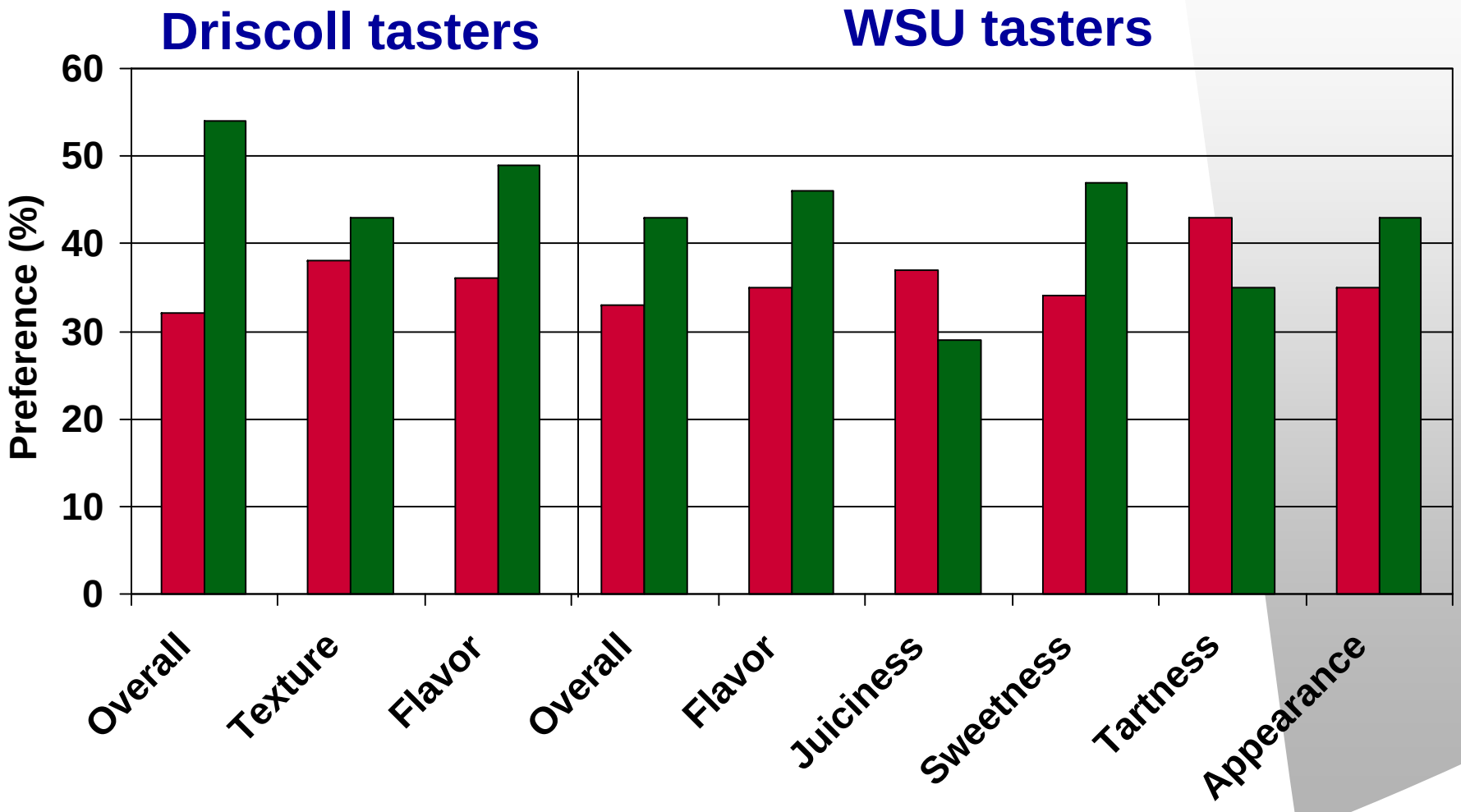

Survival distribution function
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
Time (days)
ORG
CON
Wilcoxon P > X² < 0.0001
Grey mold

Consumer preference

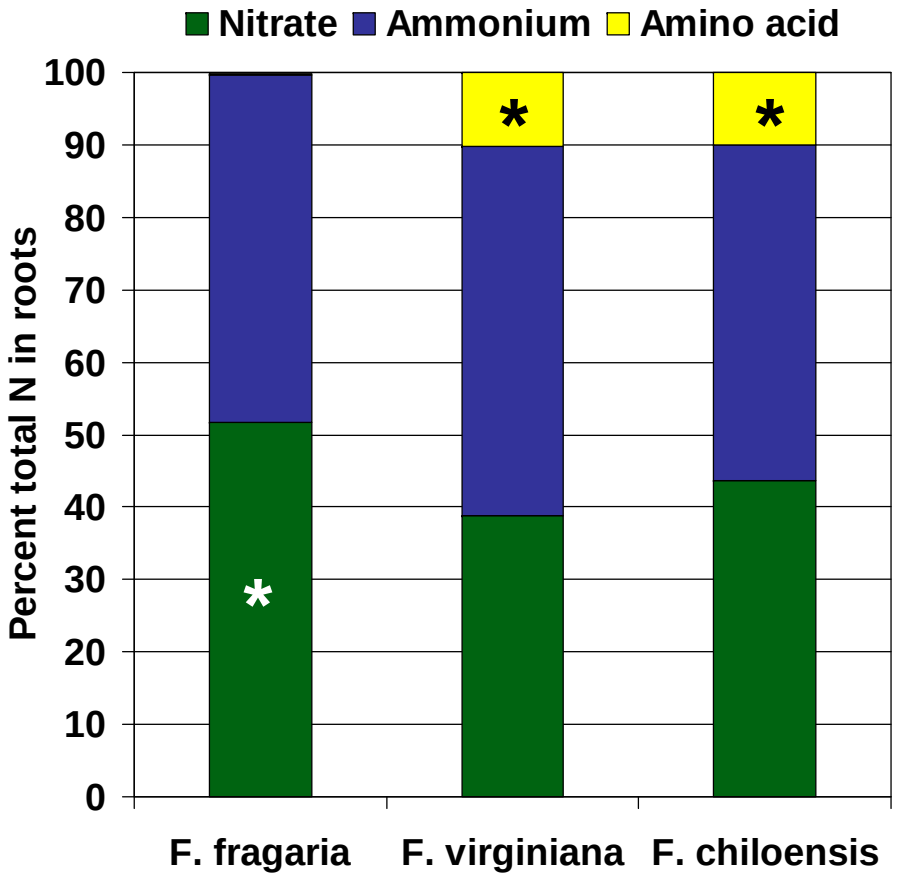


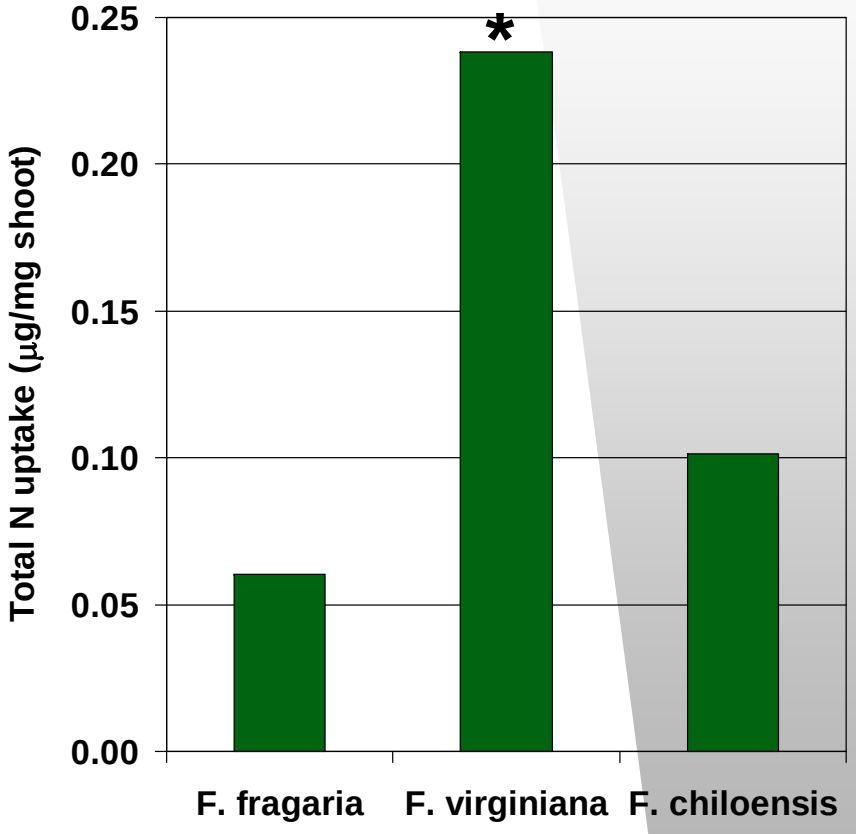
WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Consumer preference



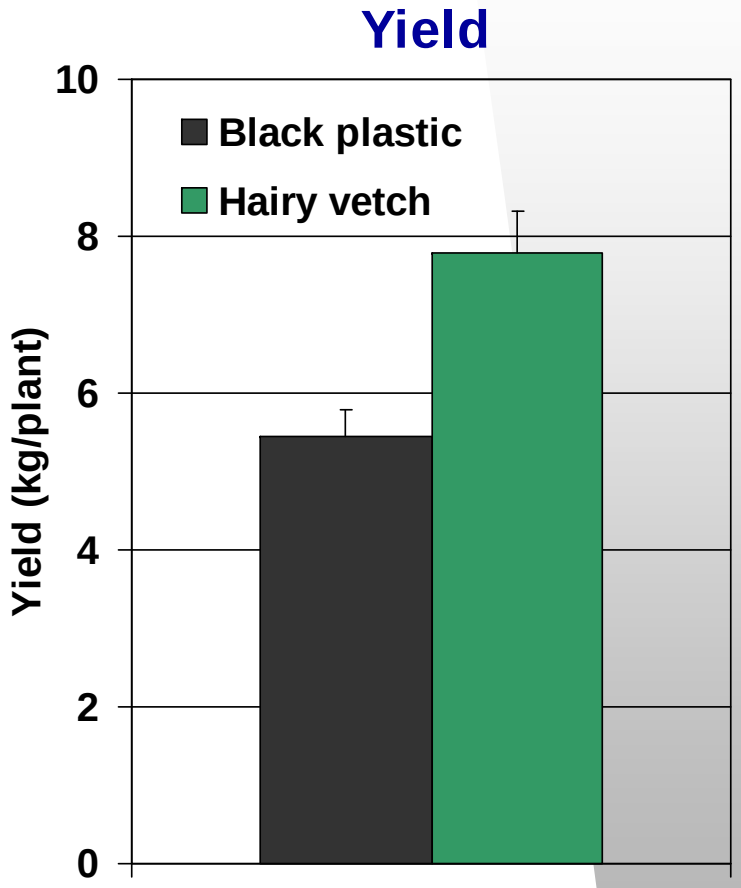
Nitrogen uptake by strawberries





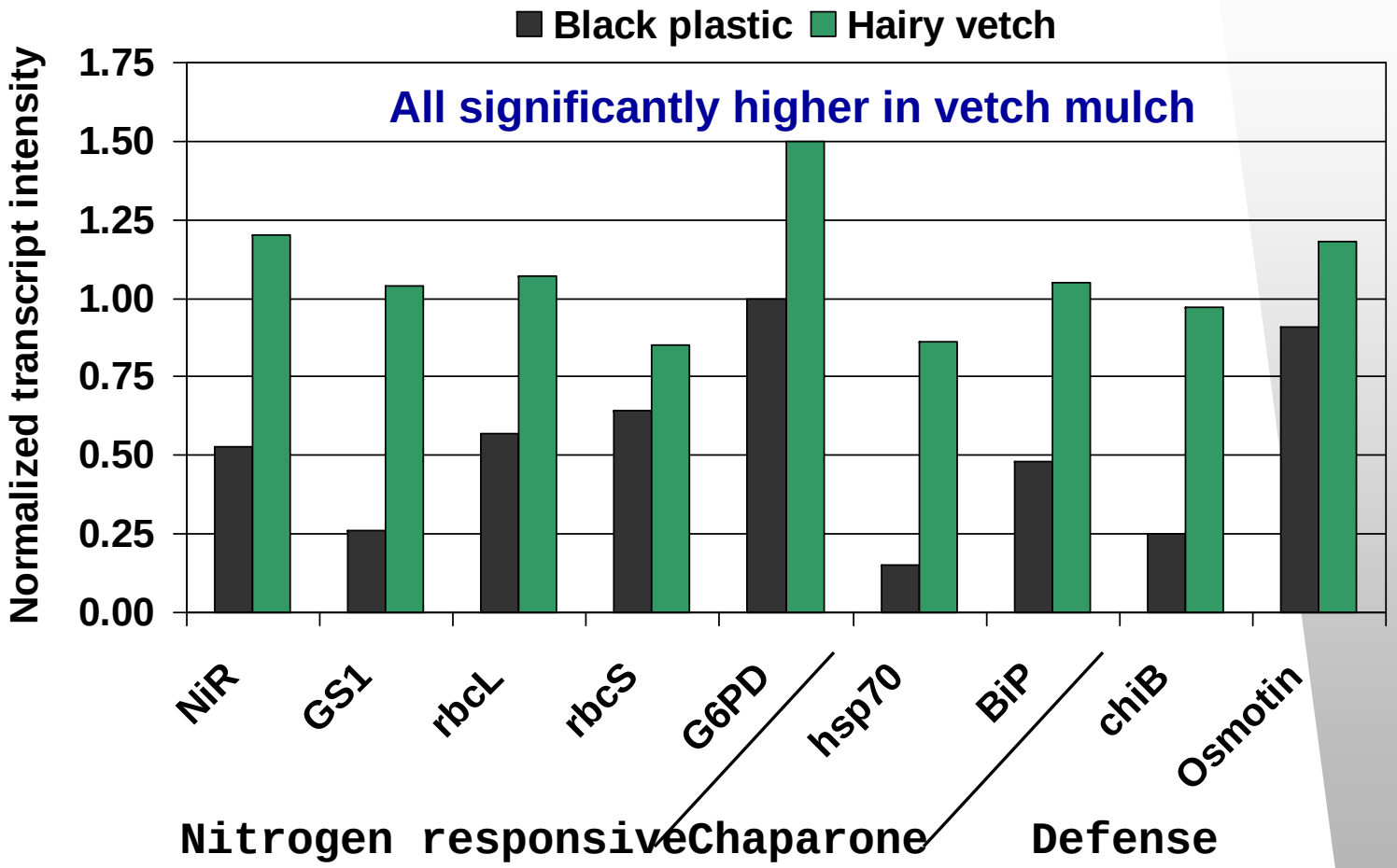
Reeve et al., Soil Biol & Biochem (2008)

Tomato mulch studies
USDA Beltsville



Neelam *et al*, *J Expt Bot* (2008)

Gene expression in tomato leaves



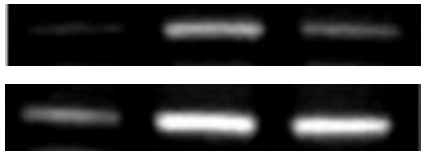
Kumar *et al*, *Proc Natl Acad Sci* (2004)

Senescence genes in tomato leaves

Cytokinin-responsive → delays senescence

Black plastic

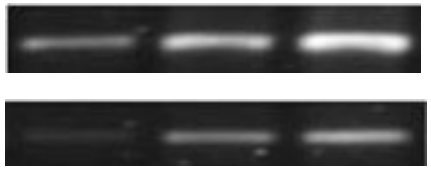
Hairy vetch



ACC synthase → hastens senescence

Black plastic

Hairy vetch



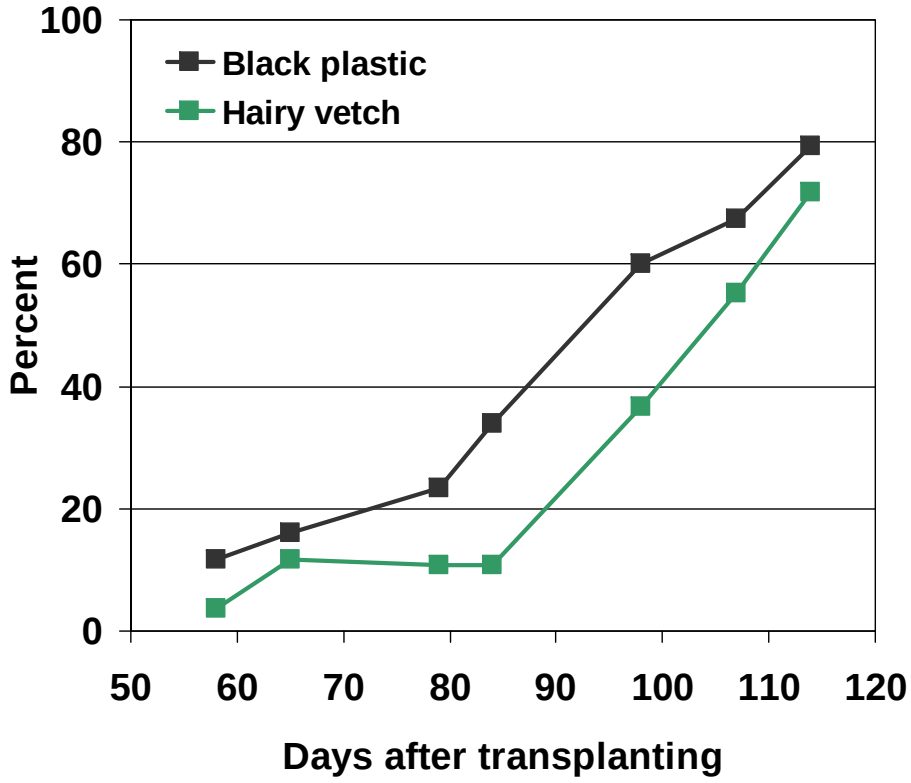
80 96 108

Days after transplanting

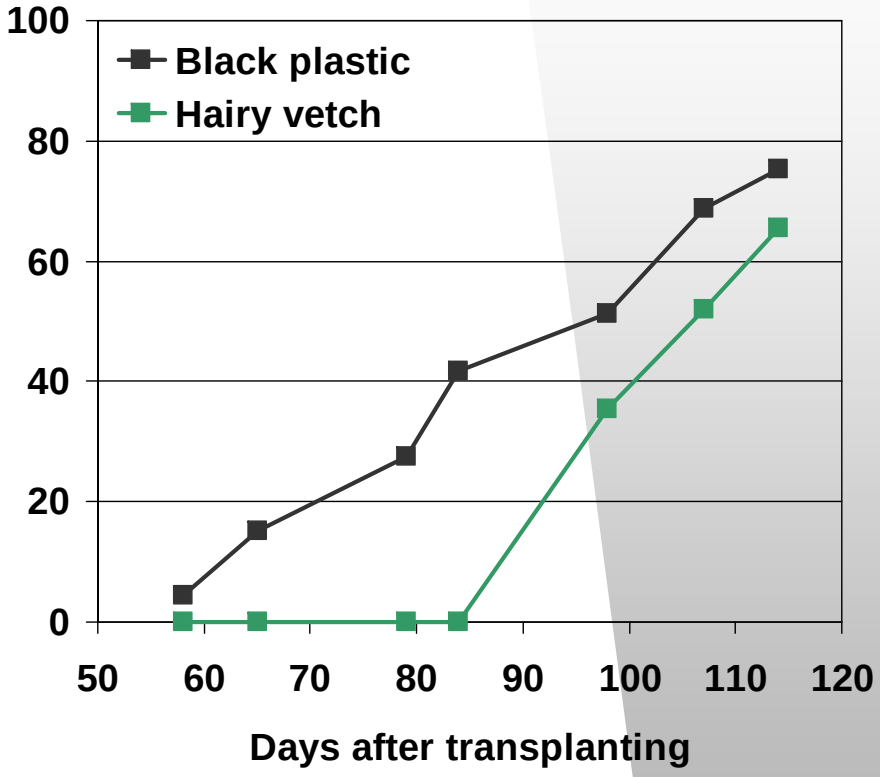
ACC: 1-aminocyclopropane-1-carboxylate

Reduced senescence & disease

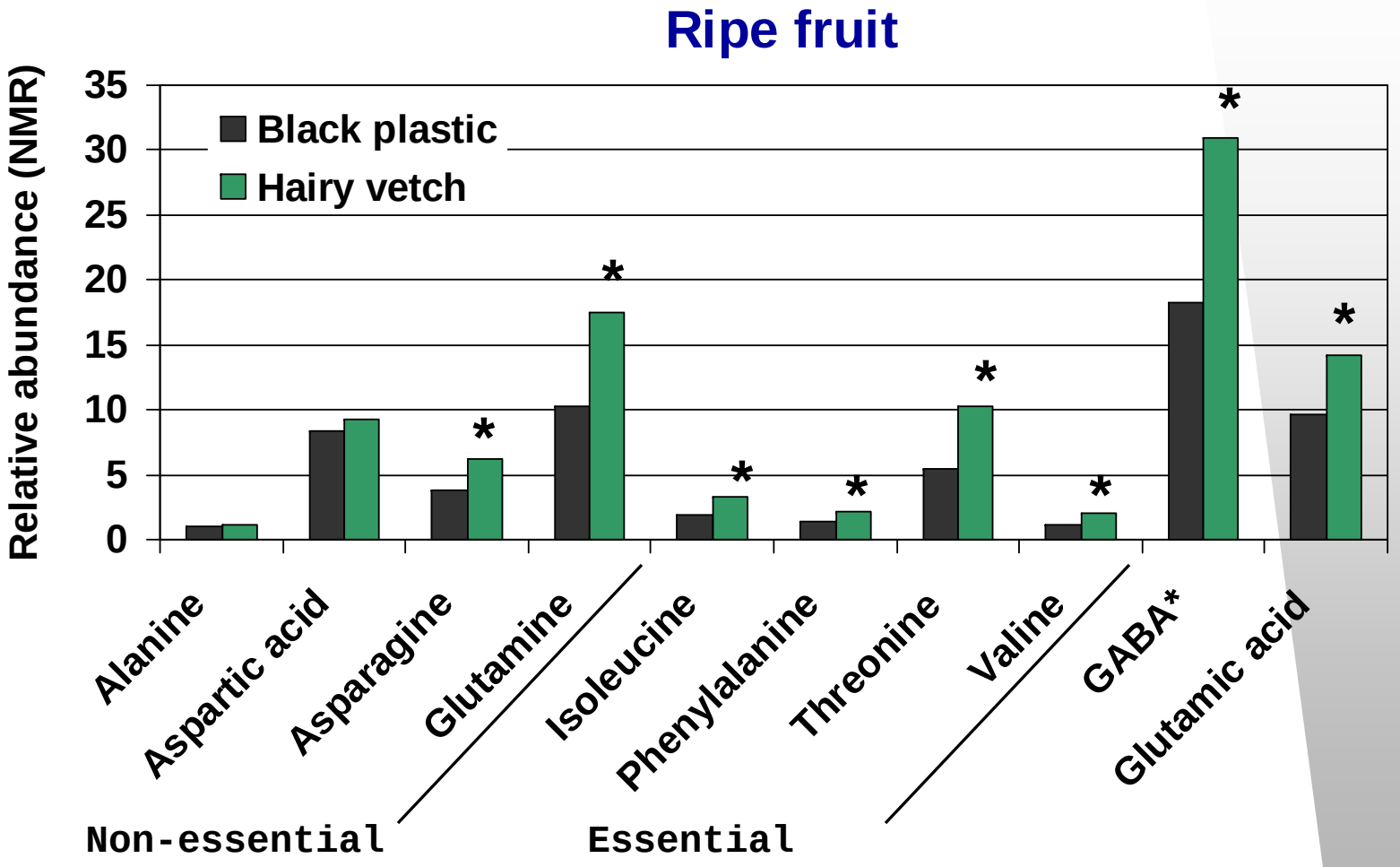
Leaf senescence



Foliar diseases



Amino acids in tomato fruit



GABA: Gamma amino butyric acid

Neelam *et al*, *J Expt Bot* (2008)

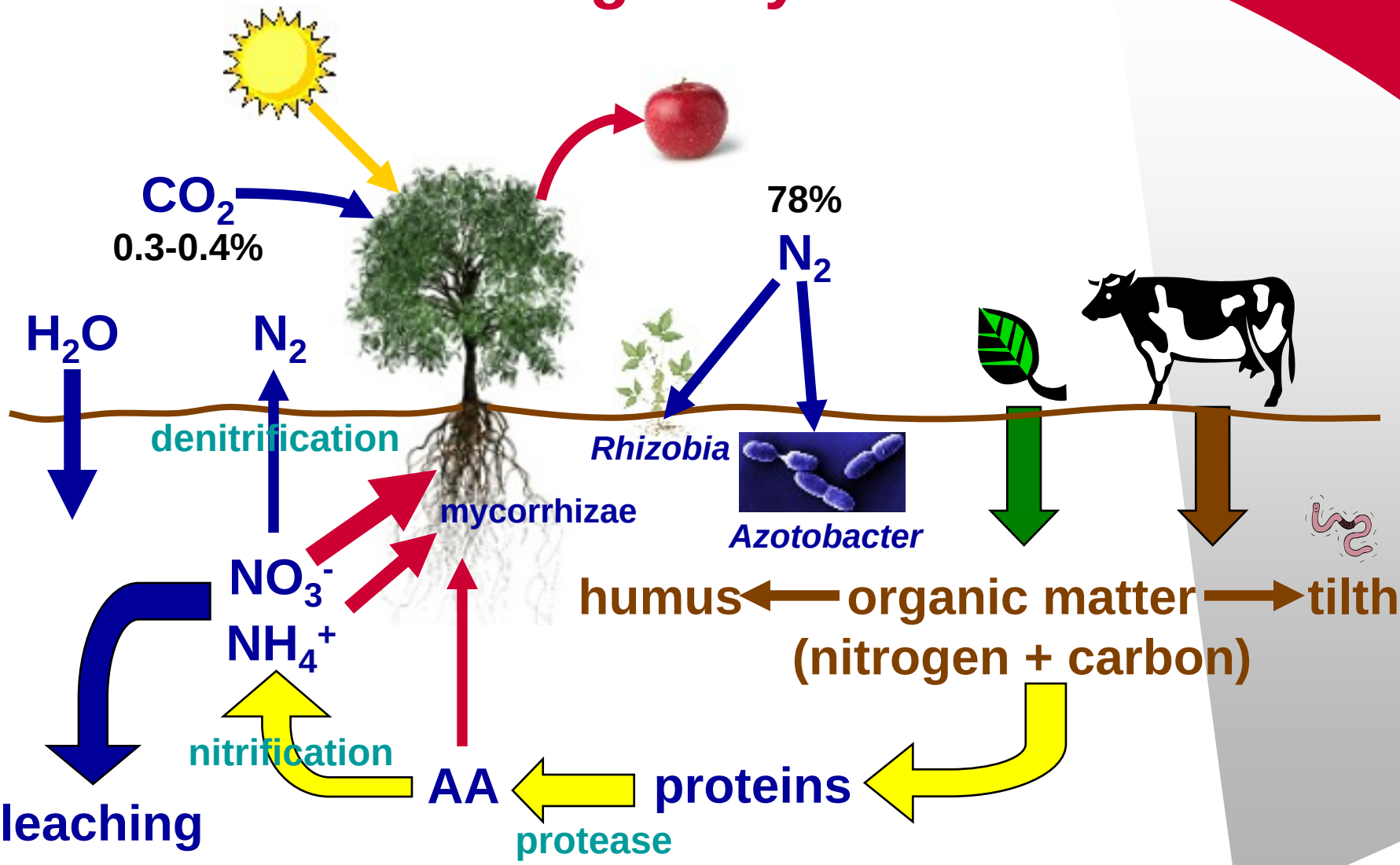
Characteristics of “living soil”

- Inputs of organic amendments & fertilizers (compost, plant litter, etc)
- High microbial populations, biological diversity & metabolic activity
- High total carbon & nitrogen, but equal or lower readily available nitrogen




WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Carbon and nitrogen cycles



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Conclusions

- Although specific mechanisms and soil-plant interactions are ill-defined, there appears to be a link between soil health and fruit quality.
- Based on research that aims to build soil organic matter, fruit quality appears to be improved.
- Is it enough improvement to warrant the investment?
- Perhaps as inorganic fertilizer costs increase, regional efforts to produce compost and other sources of organic nutrients will gain favor.

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Supporting organizations

USDA United States Department of Agriculture
Cooperative State Research, Education, and Extension Service

WASHINGTON TREE FRUIT RESEARCH COMMISSION
"Committed to bringing you quality research."

ORGANIC FARMING RESEARCH FOUNDATION

The Organic Center

Center for Sustaining Agriculture & Natural Resources

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Questions?

"Where no kind of manure is to be had, I think the cultivation of lupines will be found the readiest and best substitute."

Columella, 1st century Rome

"Organic matter functions mainly as it is decayed and destroyed. Its value lies in its dynamic nature."

W.A. Albrecht, 1938

"Grass is a source of strength of agriculture and, therefore, to the nation."

Henry Wallace, 1940