New Farming Systems and Their Impact on Quality

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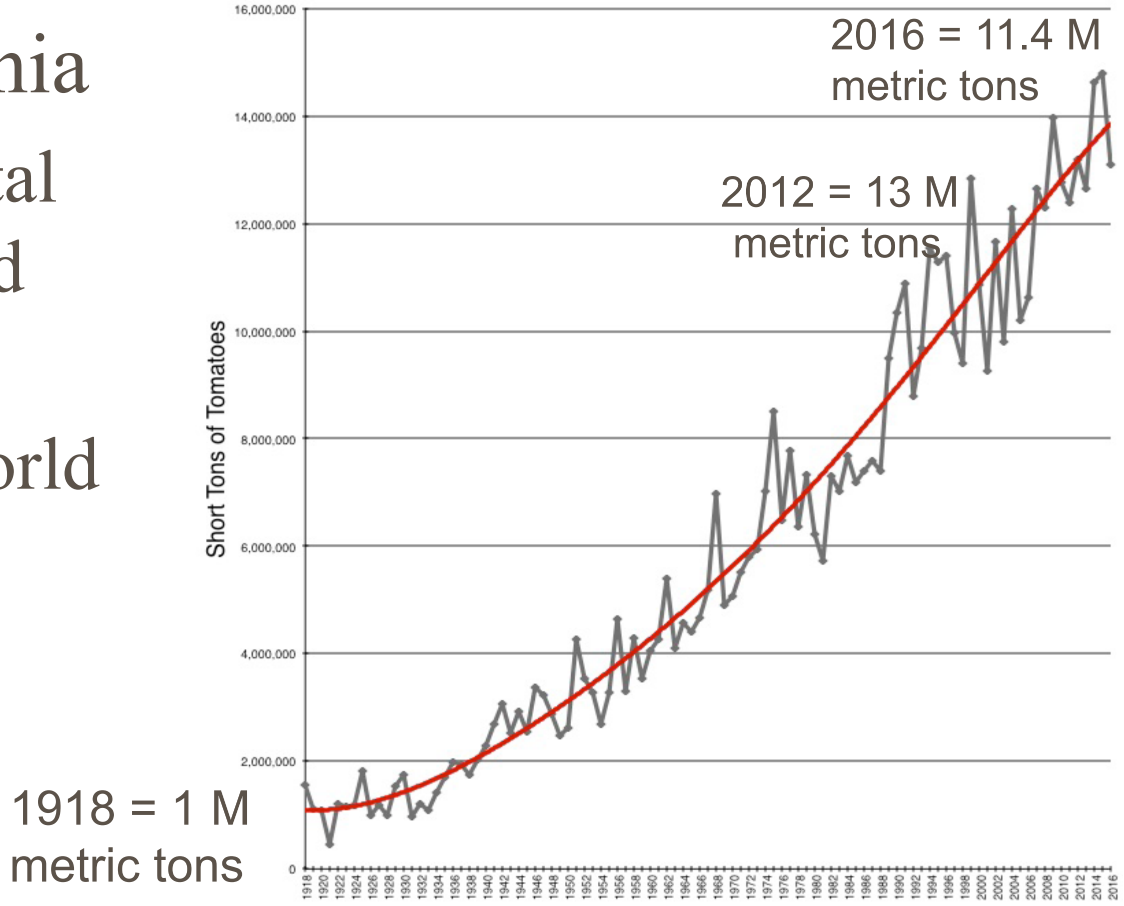
Outline of Presentation

- California Tomato Industry & Funding
- Organic vs. Conventional Farming
  - 3 Industry-Funded On-Farm Studies
    - 2000 Stahlbush Island Farms
    - 2004 Muir Glen / General Mills
    - 2006 Campbell's Soup
  - UC Davis Study – 100 Year Study
- Drought Tolerance
- On-Farm vs. Field or Lab Studies




2016 California Tomato Statistics

- State of California
  - 95% of the total U.S. processed tomatoes
  - 25% of the world processed tomatoes



2016 California – France Comparison

- California
  - 105,218 Ha
  - Yield = 91.6 tons/Ha
  - 9,979 metric tons tomato paste
  - Product
    - 75% tomato paste
    - 25% dice, whole peel

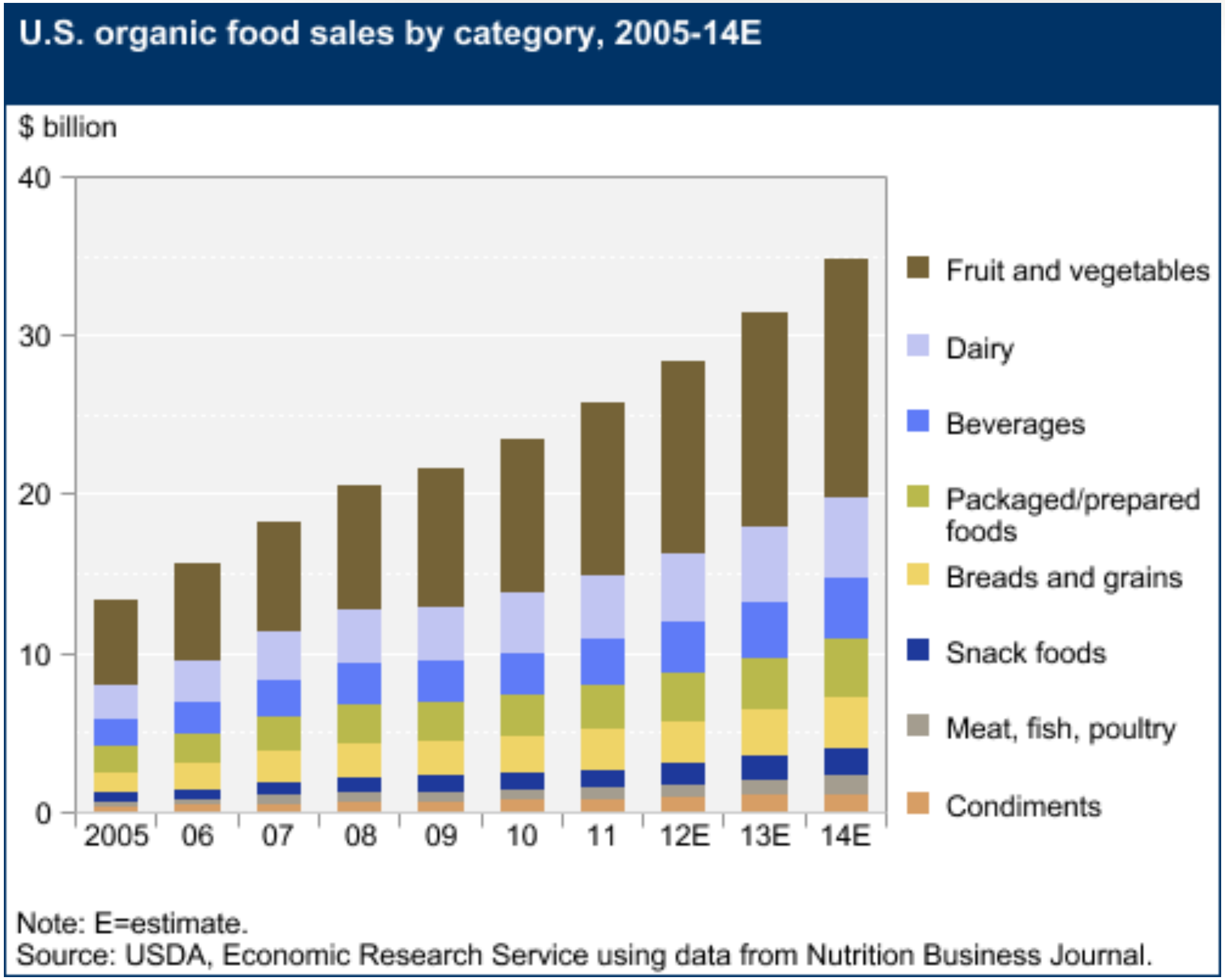
- France
  - 2,490 Ha
  - Yield = 74.2 tons/Ha
  - 183,000 metric tons tomato paste
  - Product
    - 87% tomato paste
    - 13% dice, whole peel

Processor	Facility Location	Year Built	Tomato Capacity for Tomato Paste (Tons/Hour)	Equivalent Tomato Paste (Pounds/Hour)
Marketers				
Morning Star Packing	Williams	1995	1350	442,650
Liberty Packing Company	Santa Nella	1975/02	870	285,336
Morning Star Packing	Los Banos	1990	666	218,438
Los Gatos Tomato Products*	Huron	1991	512	168,000
Olam Tomato Processors	Lemoore	1990	447	146,463
J.G. Boswell Tomato Company*	Bakersfield	2000	403	132,225
Ingomar Packing Company*	Los Banos	2000	411	134,651
J.G. Boswell Tomato Company*	Corcoran	2008	332	108,808
Ingomar Packing Company*	Los Banos	1983	348	114,238
Pacific Coast Producers*	Woodland	1943/02	294	96,532
Toma-Tek	Firebaugh	1989	249	81,766
Olam Tomato Processors	Williams	1982	249	81,553
Stanislaus Food Products	Modesto	1942	75	24,516
Sub-Total	13		6,207	2,035,175
Remanufacturers				
Campbell Soup	Dixon	1975	301	98,720
Hunt Foods	Oakdale	<1970	206	67,589
Campbell Soup	Stockton	1967	171	56,024
Ragu	Stockton	<1970	197	64,464
Del Monte	Hanford	1976	87	28,674
Sub-Total	5		962	315,470
Total	18		7,169	2,350,646

Funding for Tomato Projects

- California Tomato Research Institute
  - $465,000. in 2016, ~$4,000-$46,000./project
  - Research projects
    - Agronomic
    - Insect & disease management
    - Germplasm & variety development
- California League of Food Processors
  - $270,000. in 2014, ~$20,000-$67,000./project
  - Food processing, quality, safety

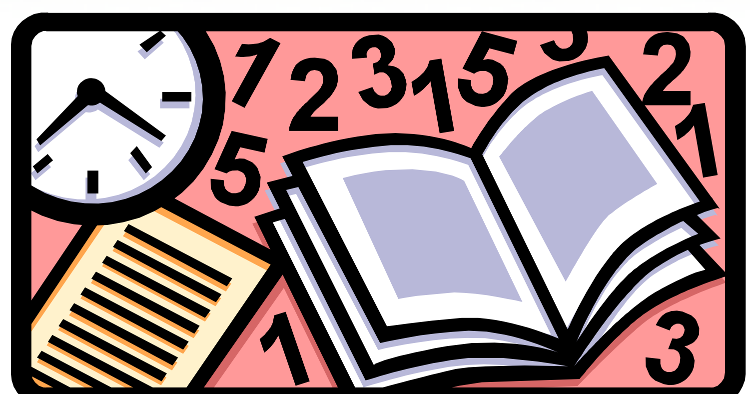
Organic Industry in the U.S.



F&V = #1

U.S. Organic food sales = $35 billion in 2014, >4% total sales.

And for the data….
Is there really a quality difference??



Nutritional Differences – Organic & Conventional Production

- Asami, Hong, Barrett & Mitchell, 2003
  Stahlbush Island Farms, California & Oregon
  - 3 crops – berries, strawberries, corn
  - 3 prod - organic, sustainable & conventional
  - 3 preservation – frozen, freeze-dried, air-dried
- Statistically higher levels of total phenolics in organic and sustainably grown berries & corn, frozen strawbs
- Ascorbic acid higher in organic and sustainably grown strawberries and corn
- 1st U.S. paper to show nutritional advantage to organic

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Asami et al., 2003; Mitchell & Barrett, 2004

Agricultural Practices

- “Real life growers”
- Took practices “as is” and documented them
- Same cultivars grown under all conditions
- Previous studies varied in ability to define practices

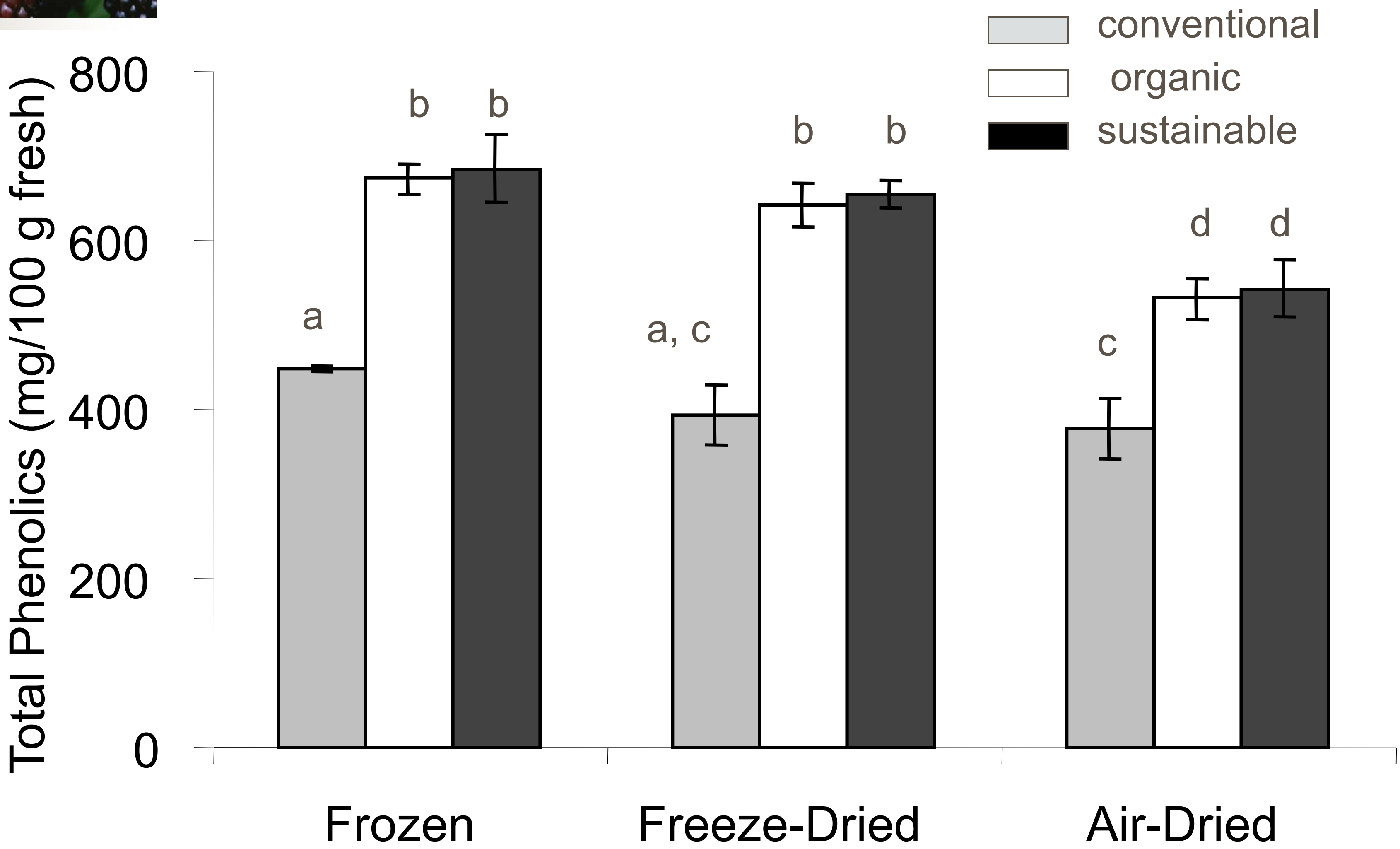
Cultural Practices Documented

Crop	Agric. Practice	Soil	Age	Previous Crop	Irriga -tion	Chem Applic.
Marion	Conv		21		Creek	
	Org		4		Creek	
	Sust		2		Well	
Strawb	Conv	Clay, loam	2		Well	Glyphosate
	Sust	same	1		Well	
Corn	Conv	Sandy		wheat	Well	Partner
	Org	Sandy, clay,loam		Green beans	Creek, well	none
	Sust	Clay, loam		Squash	same	Glyphosate Frontier

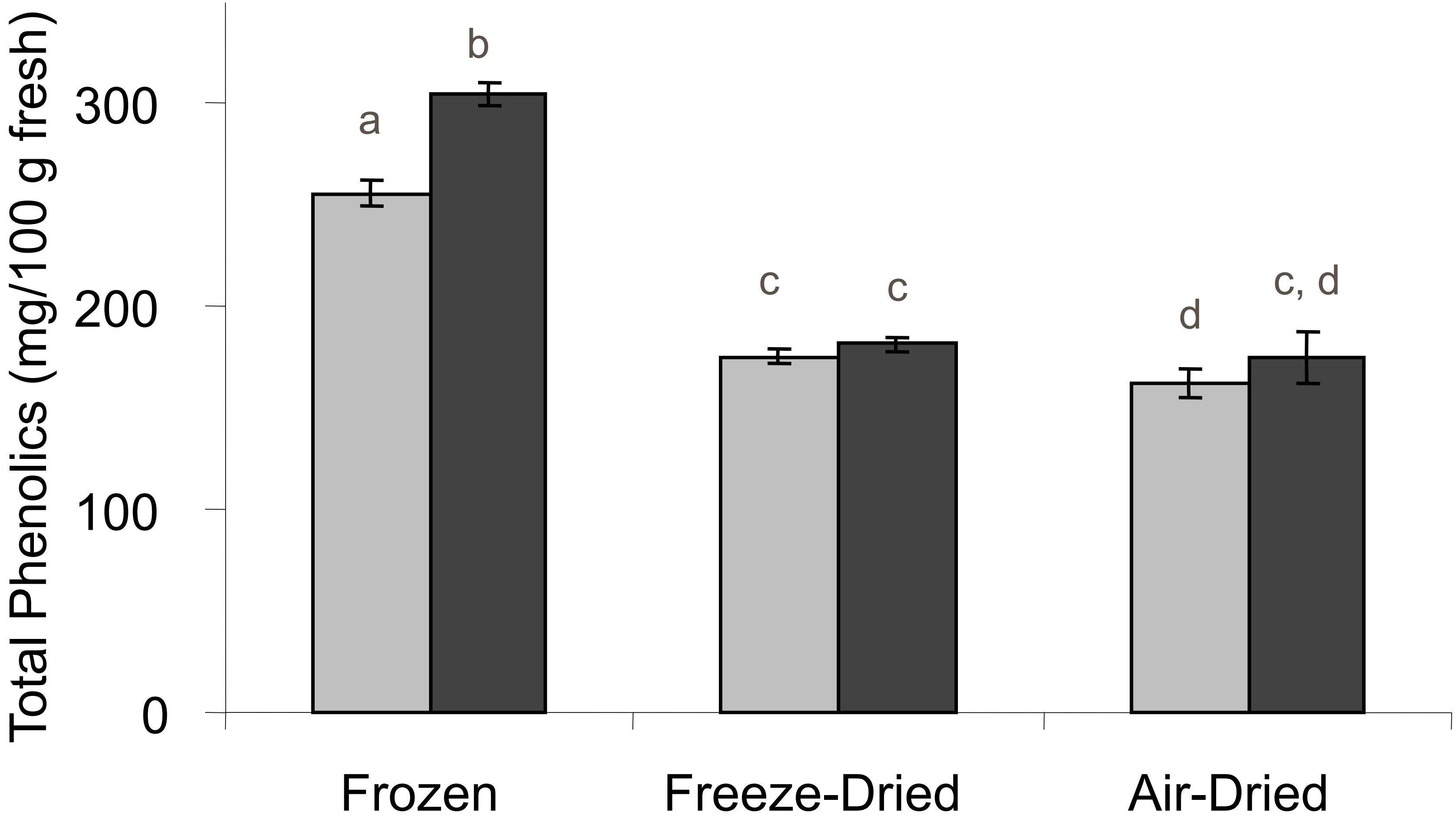
Fertilizer Rates

Crop	Agric. Practice	Fertilizer	Descrip	Rate	Timing
Marion	Conv	Std	NA		
	Org	Cow/Chicken manure		20 lb	Post-emerg
	Sust	Ammon Nit Boron, Sol 32	32% N	1 lb/acre	post
Strawb	Conv	None			
	Sust	None			
Corn	Conv	Std	NA		
	Org	Chicken manure		14-18 yd/acre	Pre-
	Sust	Sol 32 Planting blend	32% N	17.5 gal/acre	Pre-plant

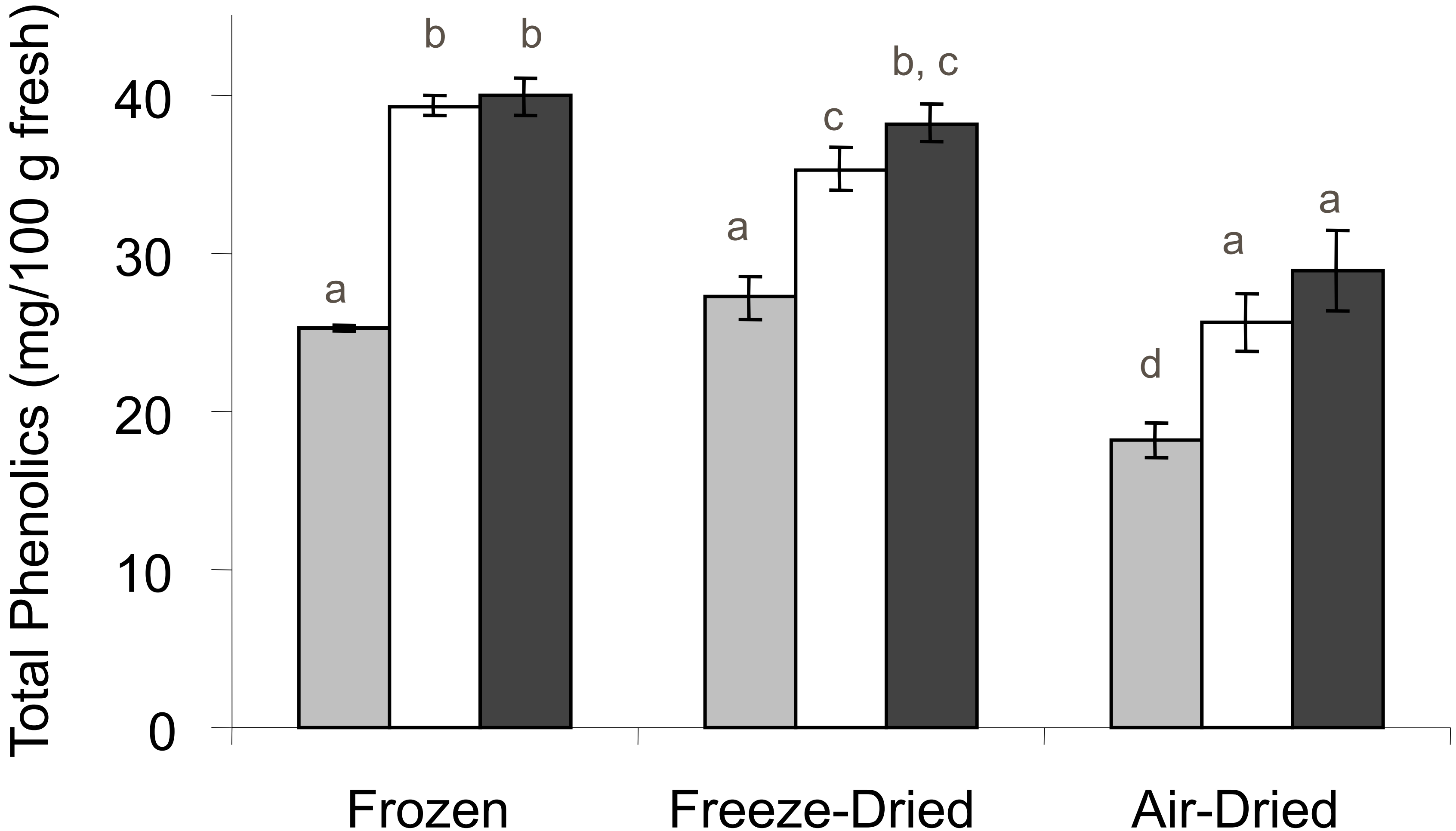
Total Phenolics in Marionberries



Total Phenolics in Strawberries



Total Phenolics in Corn



Ag Practice	Product	Ascorbic Acid (mg/100g fw)
Conventional	Frozen	nd
	Freeze-dried	nd
	Air-dried	nd
Organic	Frozen	nd
	Freeze-dried	nd
	Air-dried	nd
Sustainable	Frozen	2.9
	Freeze-dried	nd
	Air-dried	nd

Ag Practice	Product	Ascorbic Acid (mg/100g fw)
Conventional	Frozen	27.1 a
	Freeze-dried	9.8 b
	Air-dried	3.6 c
Sustainable	Frozen	32.6 d
	Freeze-dried	14.4 e
	Air-dried	5.3 f

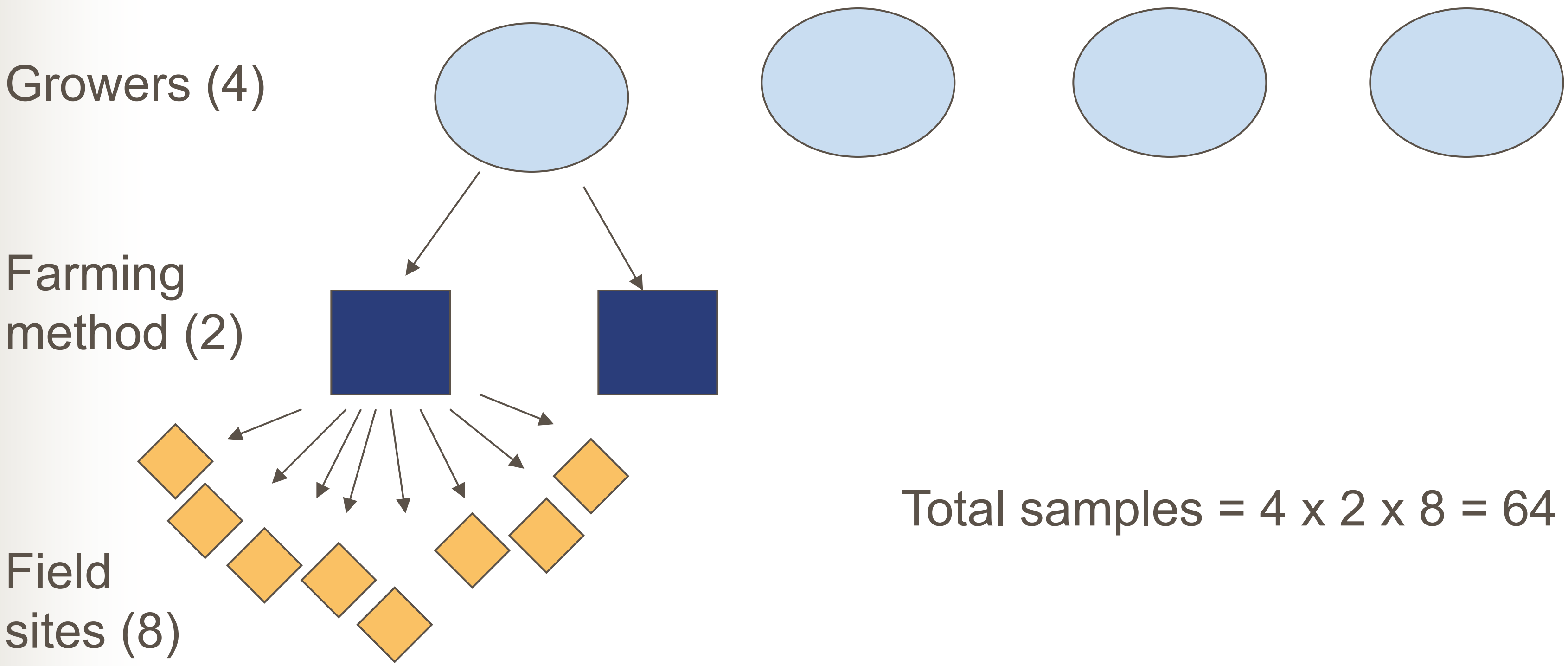
Ag Practice	Product	Ascorbic Acid (mg/100g fw)
Conventional	Frozen	2.1 a
	Freeze-dried	nd
	Air-dried	nd
Organic	Frozen	3.2 b
	Freeze-dried	nd
	Air-dried	nd
Sustainable	Frozen	3.5 c
	Freeze-dried	nd
	Air-dried	nd

Provocative Questions

- Why grow organically? Is there enough of an economic or health benefit?
- Benefit of studying "real life grower" vs. "controlled" agricultural practices? Correlation?
  - Russell Ranch 100 Year 'Experiment' at UC Davis
- Which "stress" is the important one?
  - Studies of individual stresses
  - Studies of combination of "real" stresses
- Many of these phytonutrients are toxic to the plant. Why are they good for us? In what dose? Which specific phenolics are important?

Nutritional Differences – Organic & Conventional Tomatoes

- Barrett, Diaz, Weakley & Watnik, J. Food Science, 2007

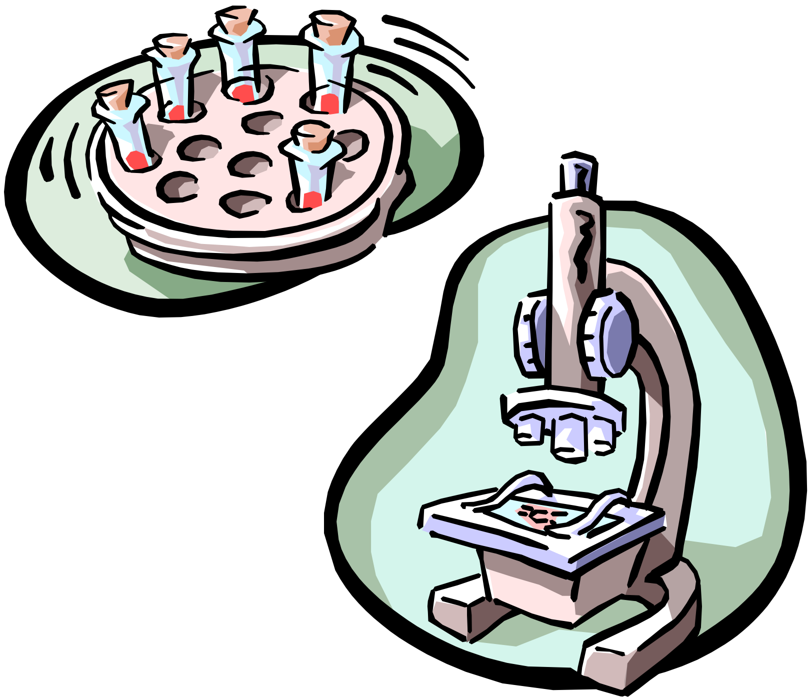


Muir Glen/General Mills

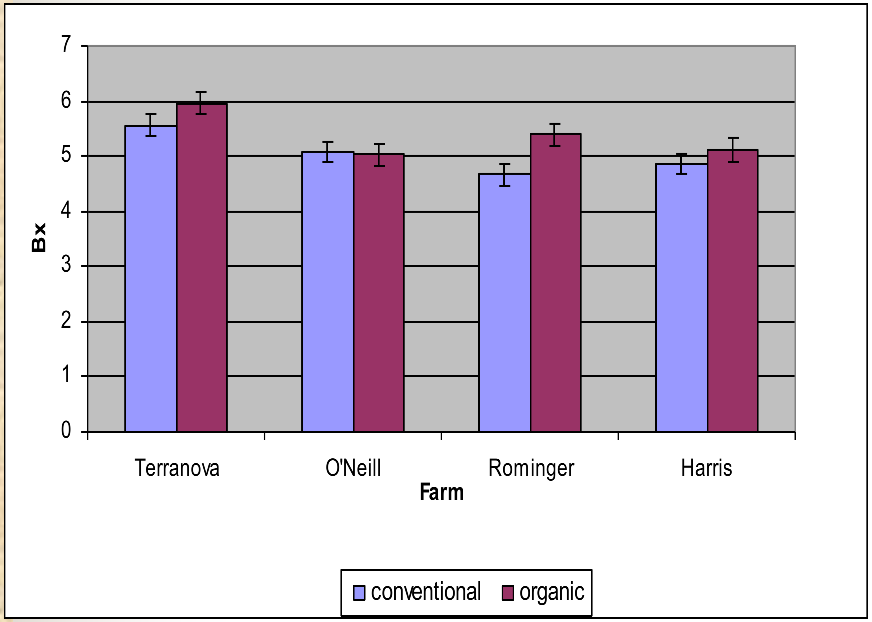
- Improved Control over Previous Project
- Each grower (x 4) had matched organic & conventional soils (USDA-NRCS)
- Three growers in Fresno, 1 in Woodland CA
- Controlled for grower skill, soil type, tomato variety, planting date, irrigation method, pesticide & fertilizer use and harvest date within each field pair
- Diff variety at each grower, maturity documented
- 8 random locations sampled per site

Quality Attributes Determined

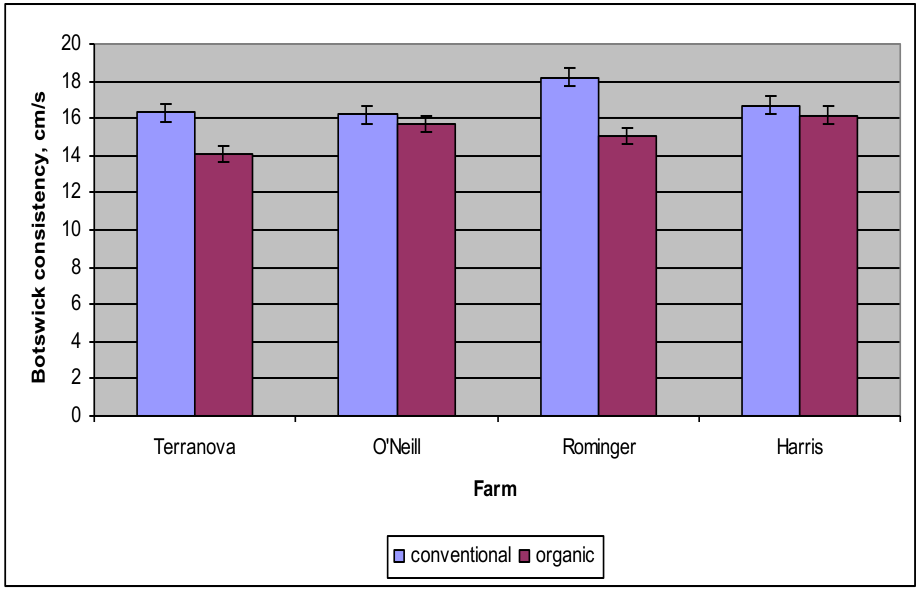
- Brix Bostwick
- pH Catsup yield
- Citric acid (T.A.)
- LED Agtron
- L, a, b Ascorbic acid
- Dehydroascorbic acid
- Lycopene
- Total phenolics
- Peelability
- Sensory – 200 consumers



Significant Differences – Organic & Conventional

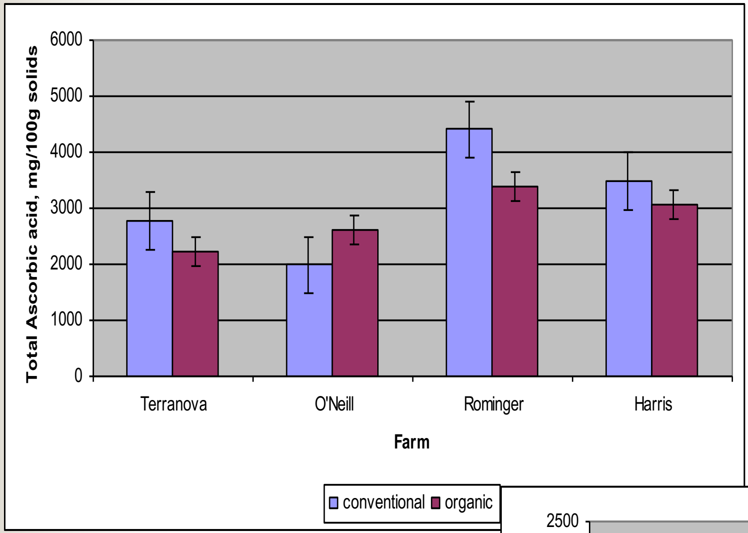


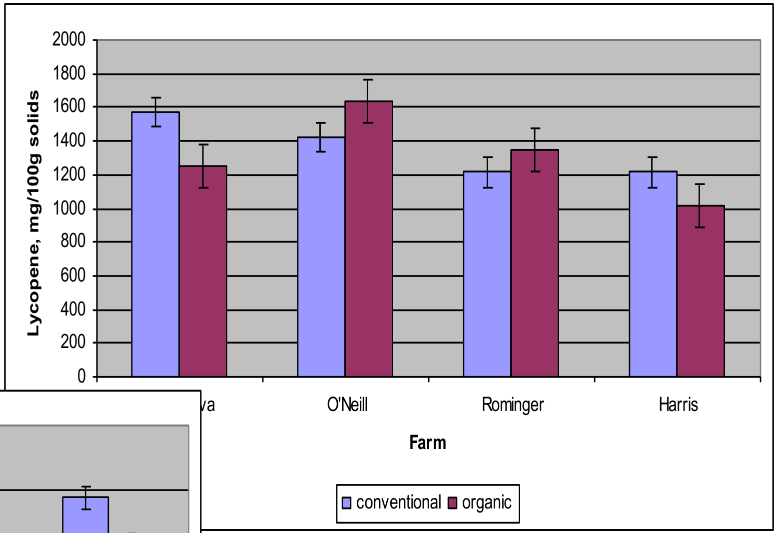
Organic:
-Significantly higher levels of Brix
-Desirably lower Bostwick consistency

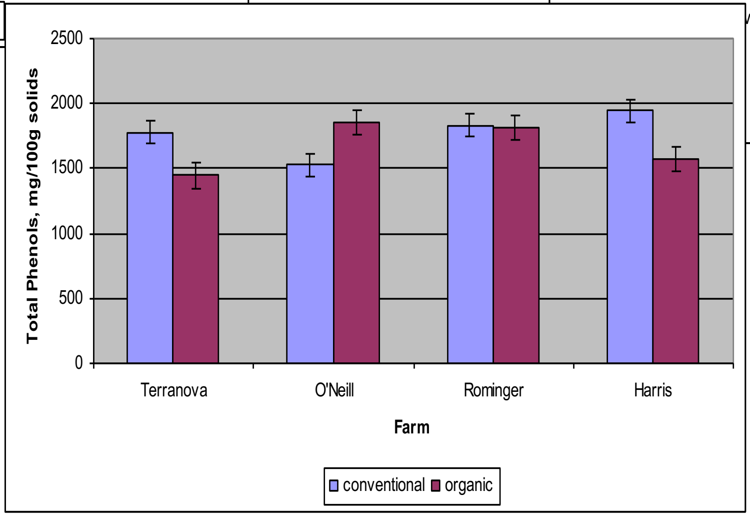


Organic also
-higher in catsup yield, titratable acidity
-lower in color and cooked phenolics

Interactions – Organic & Conventional







- -Ascorbic acid,
- -Dehydroascorbic,
- -Lycopene,
- -Total Phenolics

No Sig Difference:

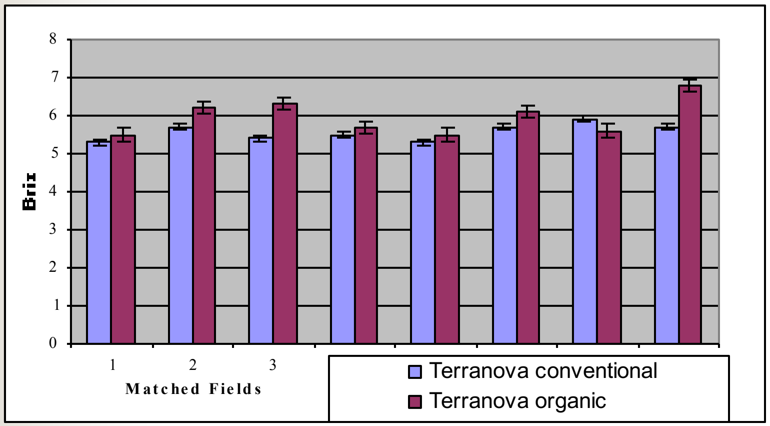
-Sensory

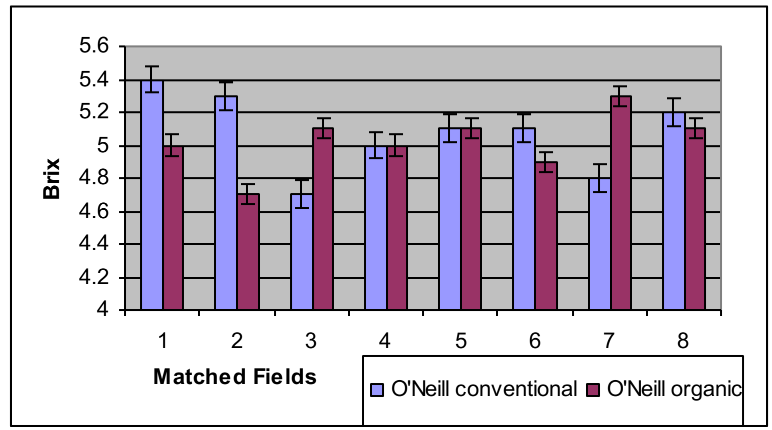
(flavor, color, texture, overall acceptability)

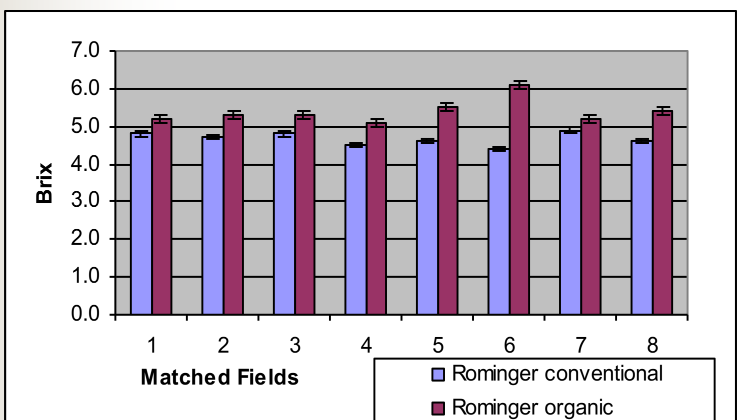
-Peelability

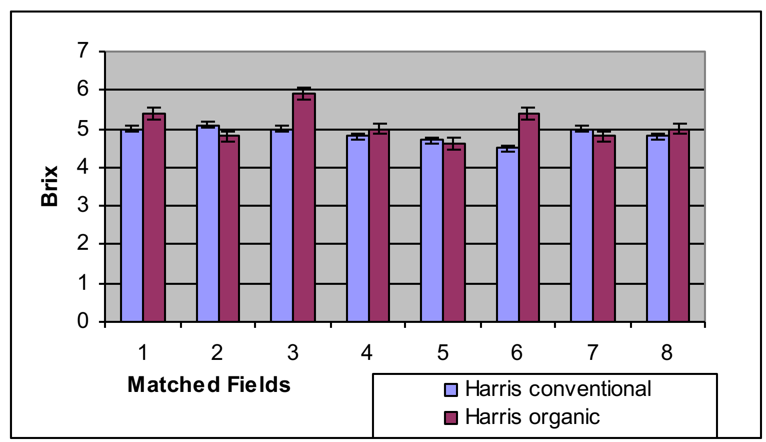
Barrett & Weakley, 2004

Within Field Variability









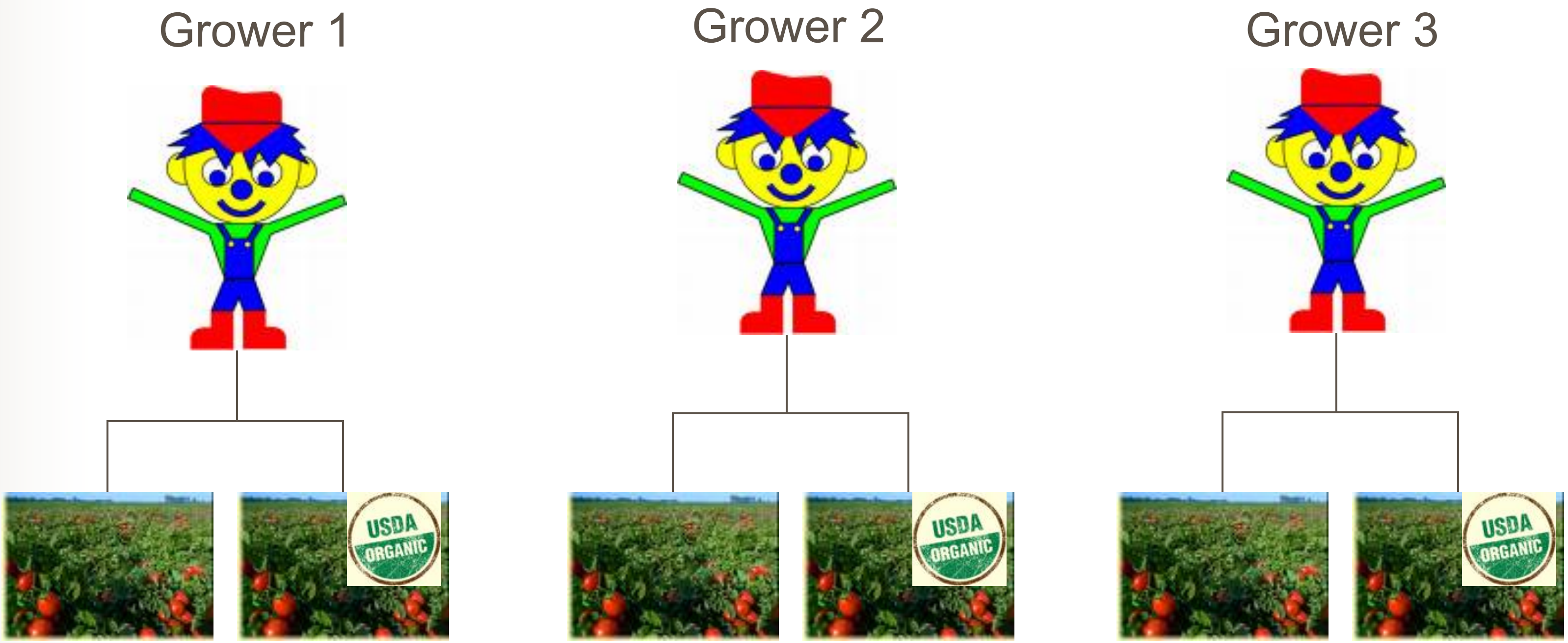
Grower Differences?

- Soil fertility
  - Nutrient composition – P, K, Mg, Ca, B, etc.
    - Theory – higher nutrient availability in conventional leads to increased plant growth; decreased C allocation to secondary plant metabolites (phenolics, glucosinolates, vitamins)
  - N release (slow in organic manures/fast in conventional)
  - Cover crops & microbial pop – more critical in organic
- Water-holding capacity
  - Soil texture & type – clay, loam, etc.
  - Limited water availability may lead to stress and increased production of polyphenolics etc.
- Geographical location
- Variety (different in each location)

Nutritional and Quality Analysis of Organic and Conventional Tomatoes: Two-Year Study

Joy Rickman and Diane M. Barrett
University of California at Davis
Food Science and Technology
J. Science of Food & Agriculture,
2 publications, 2007

Sampling Design



- 8 field locations
- Sampled fruit, soil and leaves

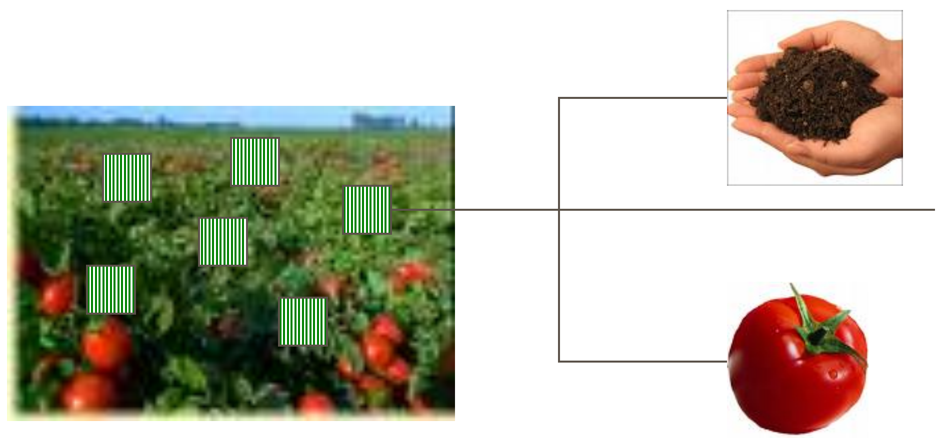


Table 1. Farm locations. planting and harvest dates

	Grower	Location		Planting date	Harvest date	Number of days from planting to harvest
2006	**Terranova Farms**	Helm	Conventional	4/8	7/31	114
			Organic	4/8	7/31	114
	Button and Turkovich	Winters	Conventional	5/13	9/7	117
			Organic	5/15	9/20	128
	Rominger Brothers Farms	Winters	Conventional	5/10	8/31	113
			Organic	5/16	9/18	125
2007	**Rominger Brothers Farms**	Winters	Conventional	4/19	8/14	117
			Organic	4/17	8/22	127
	Joe Rominger	Winters	Conventional	4/19	8/16	119
			Organic	4/11	8/16	127
	Joe Muller and Sons	Woodland	Conventional	4/7	8/15	130
			Organic	4/9	8/15	128

Analyses

- **Visual Inspection**
  - Stems
  - Size
  - Color (maturity)
  - Yellow-eye
  - Sunburn
  - Limited use
- **Quality**
  - Yield
  - Brix/NTSS
  - Bostwick
  - pH and TA
  - Color
  - Moisture content
- **Nutritional**
  - Vitamin C
  - Lycopene
  - Amino acid analysis: Glutamate, glutamine, tyrosine
  - Flavonol glycosides
- **Nitrogen and Minerals**
  - Nitrate/Ammonium
  - Nitrogen/Phosphorus/Potassium
  - Boron/Calcium/Magnesium
  - Zinc/Manganese/Iron/Copper
  - ^{15}N isotope analysis
- **Soil**
  - Nitrogen
  - Particle size
  - pH
  - Organic matter
- **Leaves**
  - Nitrogen/Phosphorus/Potassium

Significant Results

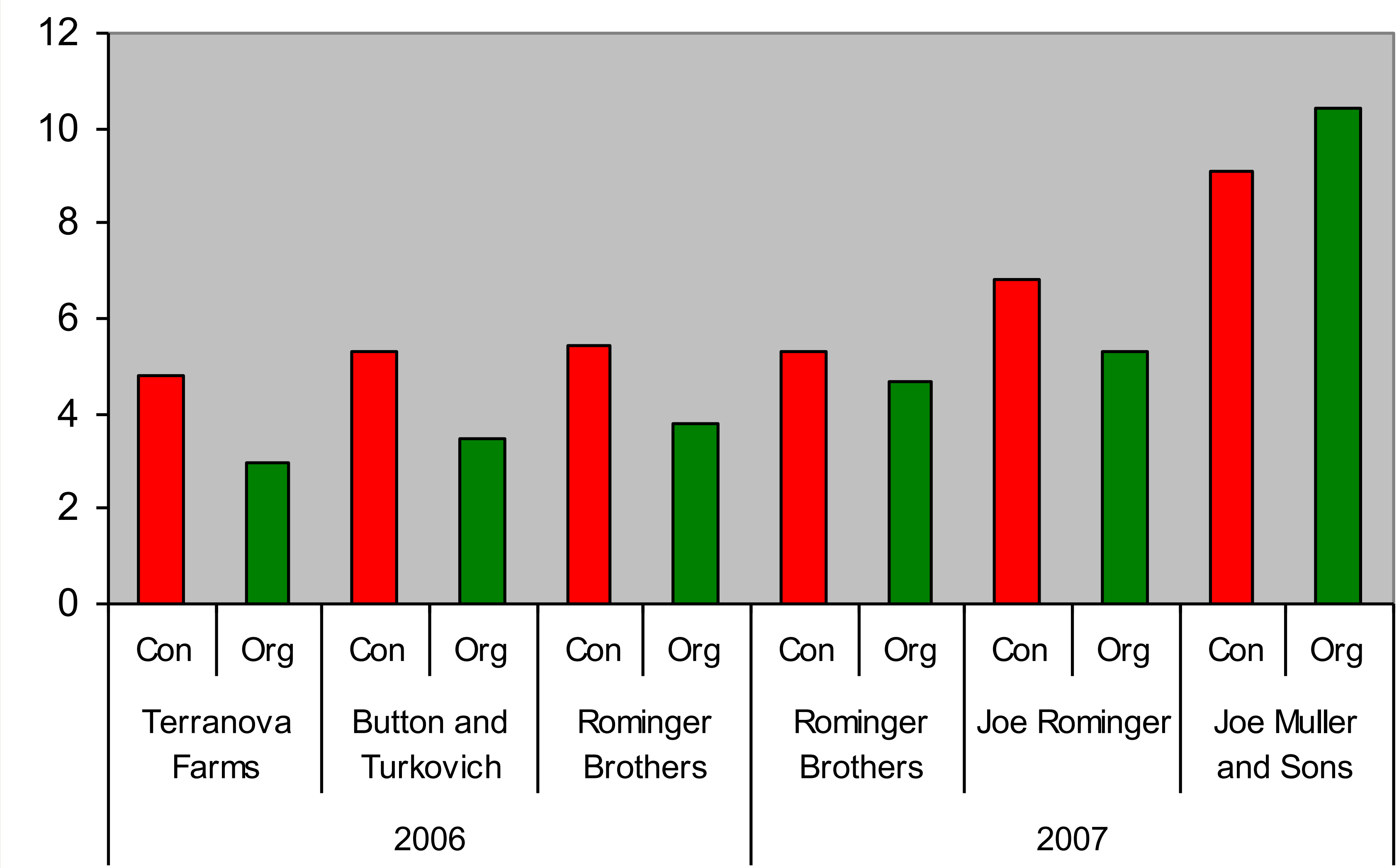
- **Visual Inspection**
  - **Stems**
  - Size
  - **Color (maturity)**
  - **Yellow-eye**
  - Sunburn
  - Limited use
- **Quality**
  - **Yield**
  - **Brix/NTSS**
  - **Bostwick**
  - pH and TA
  - **Color**
  - **Moisture content**
- **Nutritional**
  - Vitamin C
  - Lycopene
  - Amino acid analysis: **Glutamate**, **glutamine**, **tyrosine**
  - Flavonol glycosides
- **Nitrogen and Minerals**
  - Nitrate/**Ammonium**
  - **Nitrogen/Phosphorus/Potassium**
  - Boron/**Calcium**/Magnesium
  - Zinc/**Manganese**/Iron/Copper
  - **^{15}N isotope analysis**
- **Soil**
  - Nitrogen
  - **Particle size**
  - **pH**
  - Organic matter
- **Leaves**
  - Nitrogen/Phosphorus/Potassium

ANOVA was completed using SAS 9.1 Software.

Significant values: $p<0.05$

Thanks to Jerome Braun in the Statistical Computing lab for assistance

Yield Per Plant (kg)

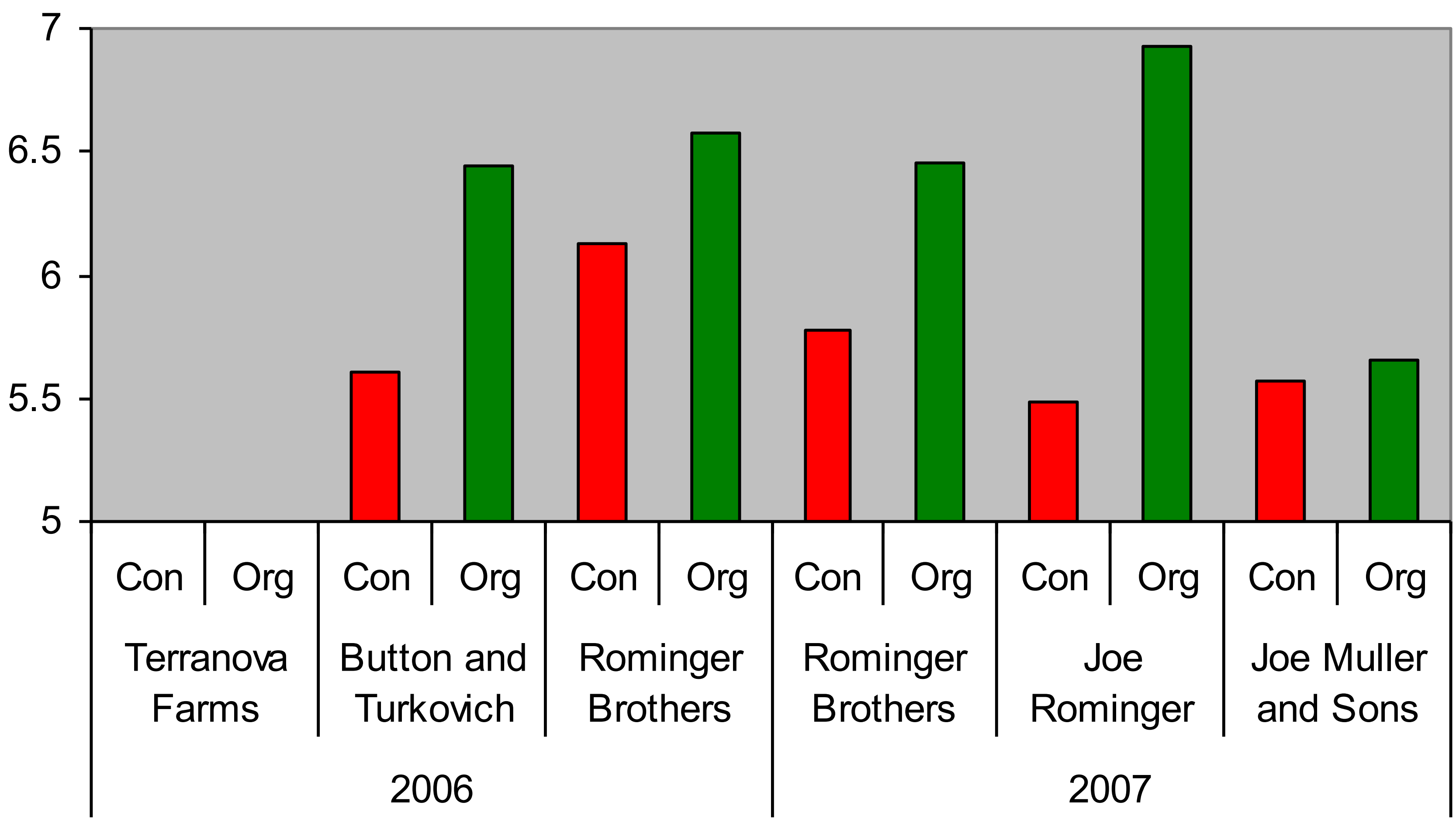


Overall difference was NOT statistically significant.

Significant Differences (+/- organic)

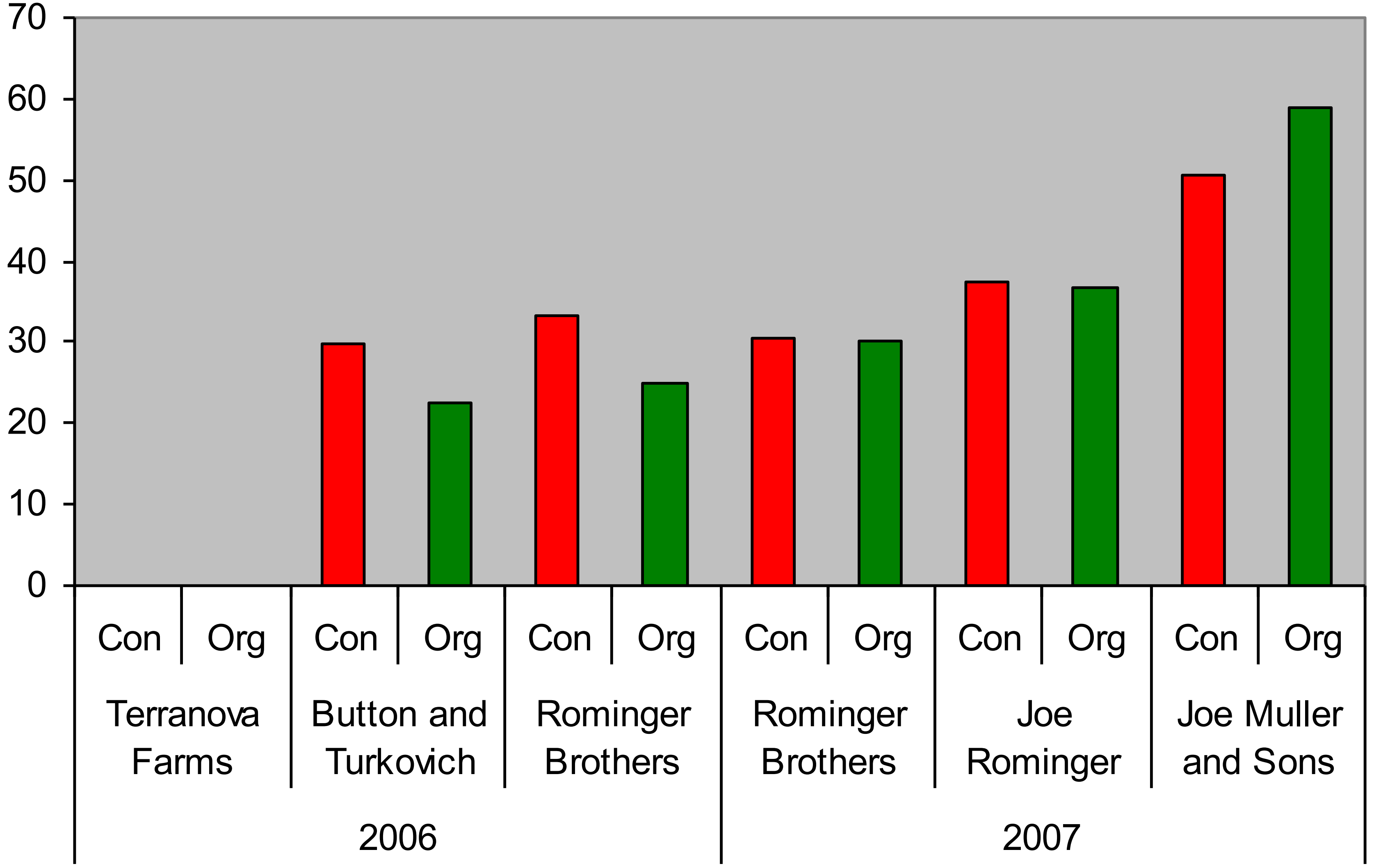
Parameter	Organic	Conventional
Percentage of red tomatoes	-	+
Percentage of attached stems	+	-
Hunter b values	+	-
Yellow-eye disorder	-	+
Soluble solids (°Brix)	+	-
Total solids	+	-
Moisture content	-	+
Bostwick consistency	-	+
Glutamate	-	+
Glutamine	-	+
Tyrosine	-	+
Total nitrogen	-	+
Ammonium	-	+
Phosphorus	+	-
Potassium	+	-
Calcium	-	+
Boron	-	+
Manganese	-	+
$\delta^{15}N$	+	-
Soil pH	+	-

Total Solids
g per 100 g



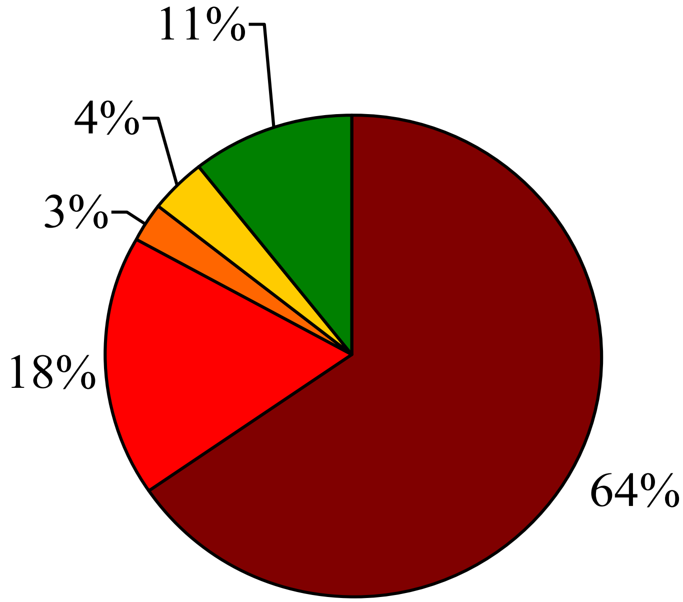
P = 0.04

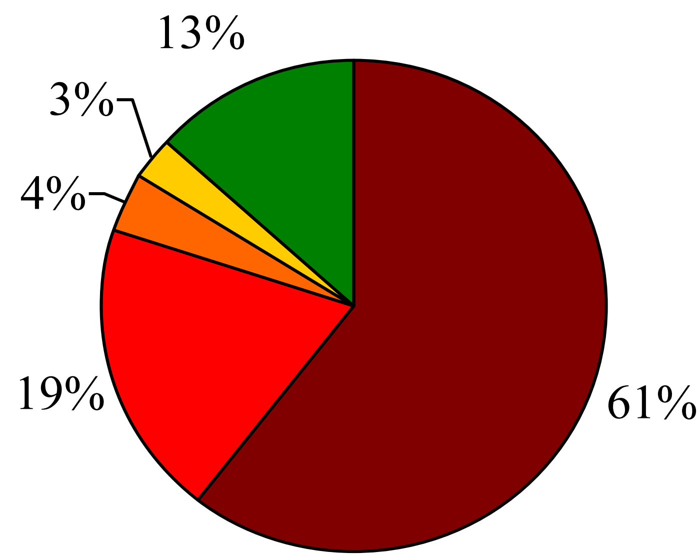
Total Solids (g per 100 g)* Yield per plant (kg)



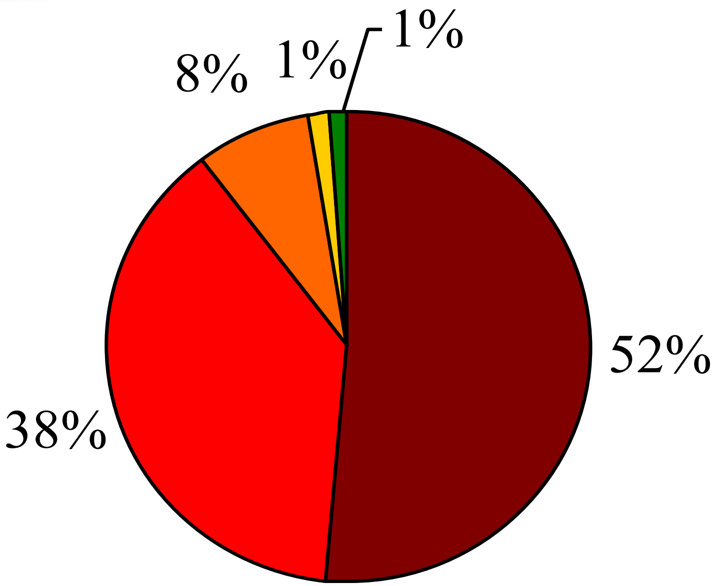
Conventional | Organic

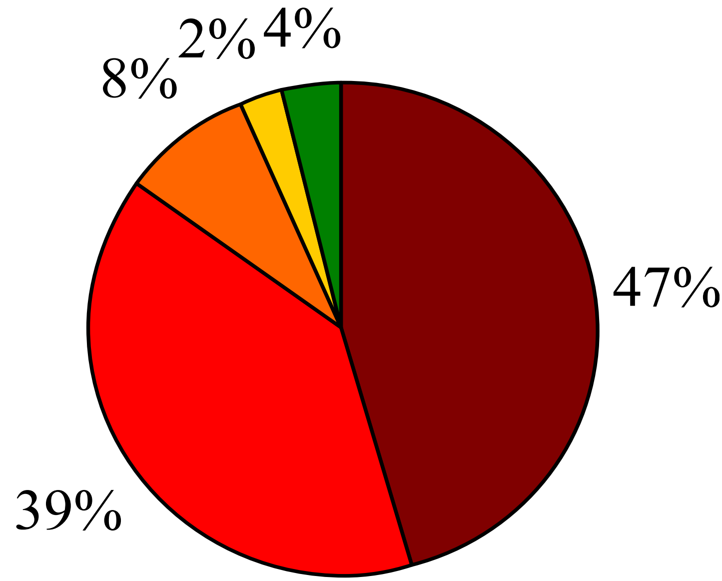
2006



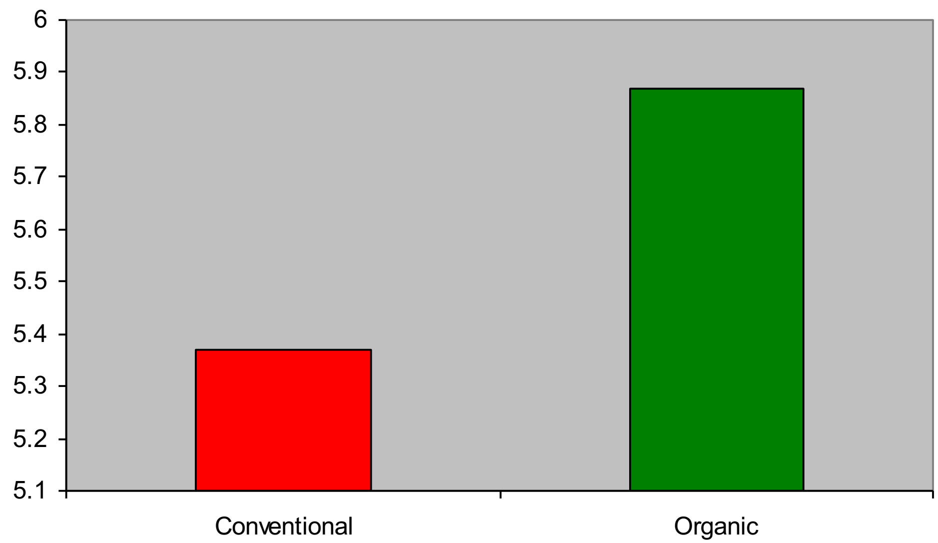


2007

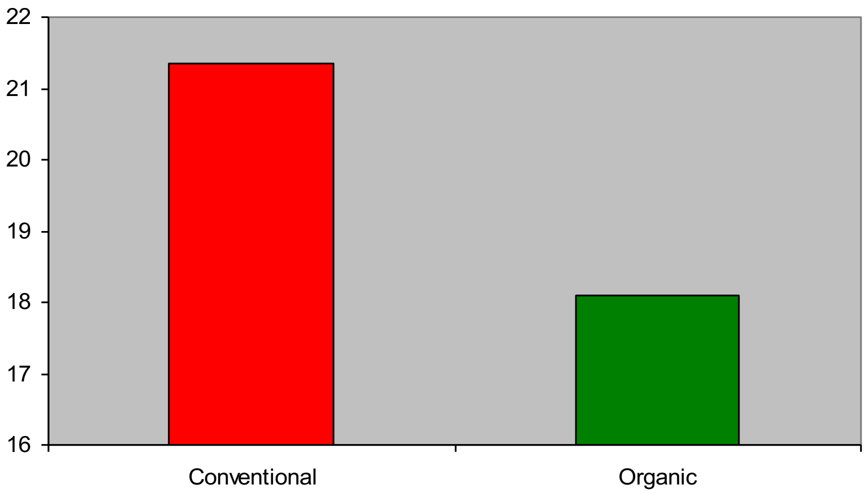




°Brix & Bostwick – Average of all growers, 2 yrs

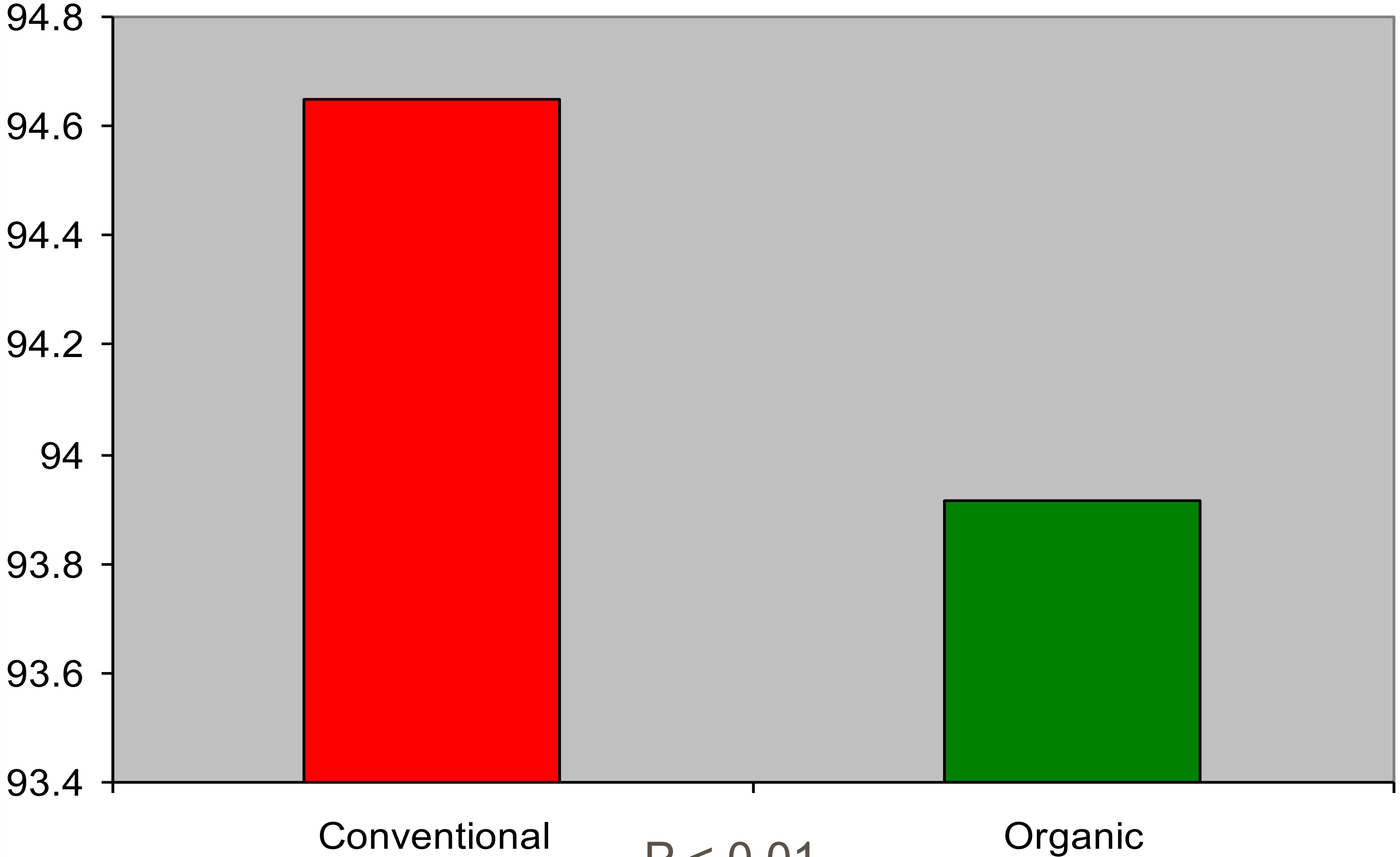


P = 0.05



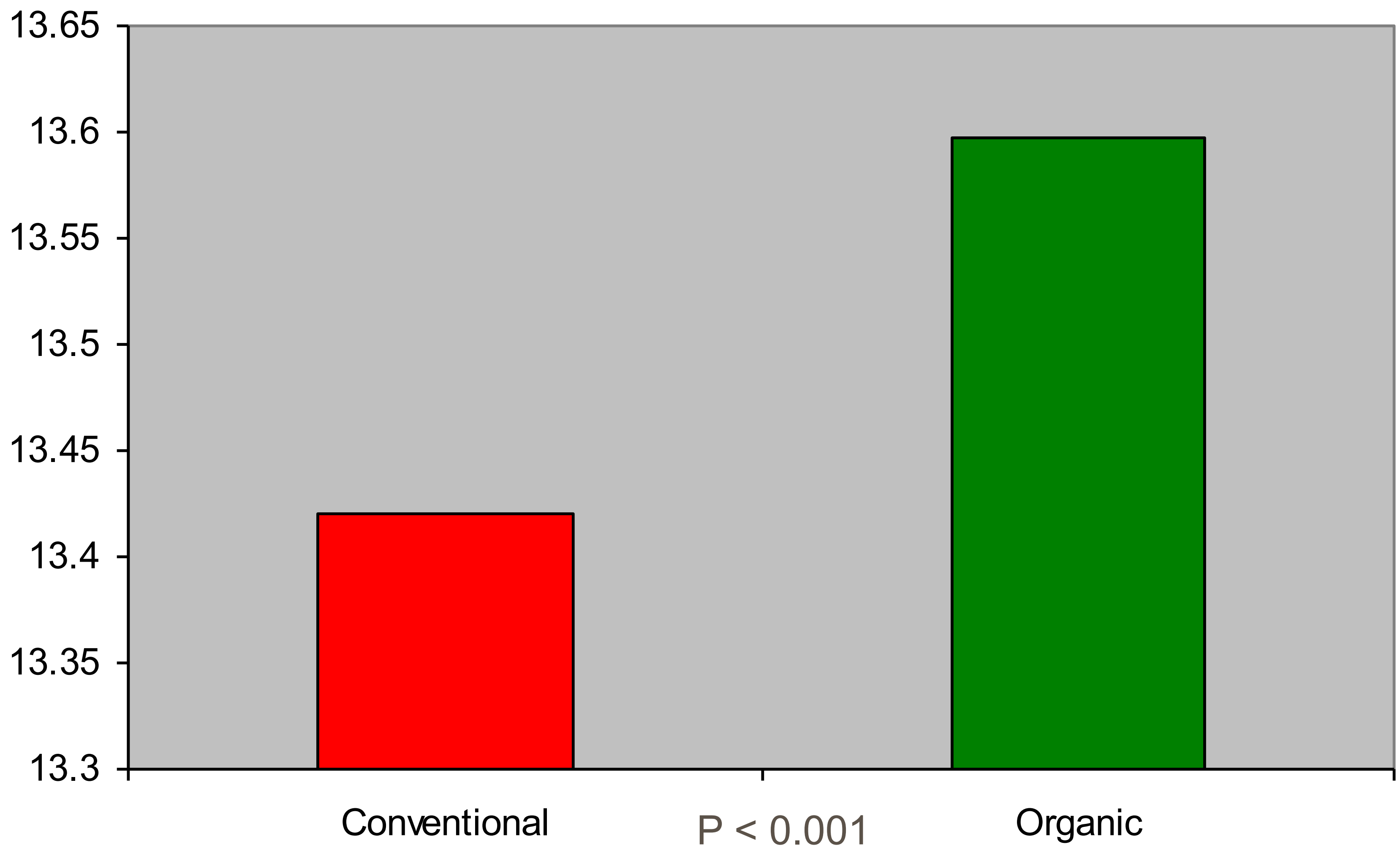
P < 0.01

Moisture Content (%)

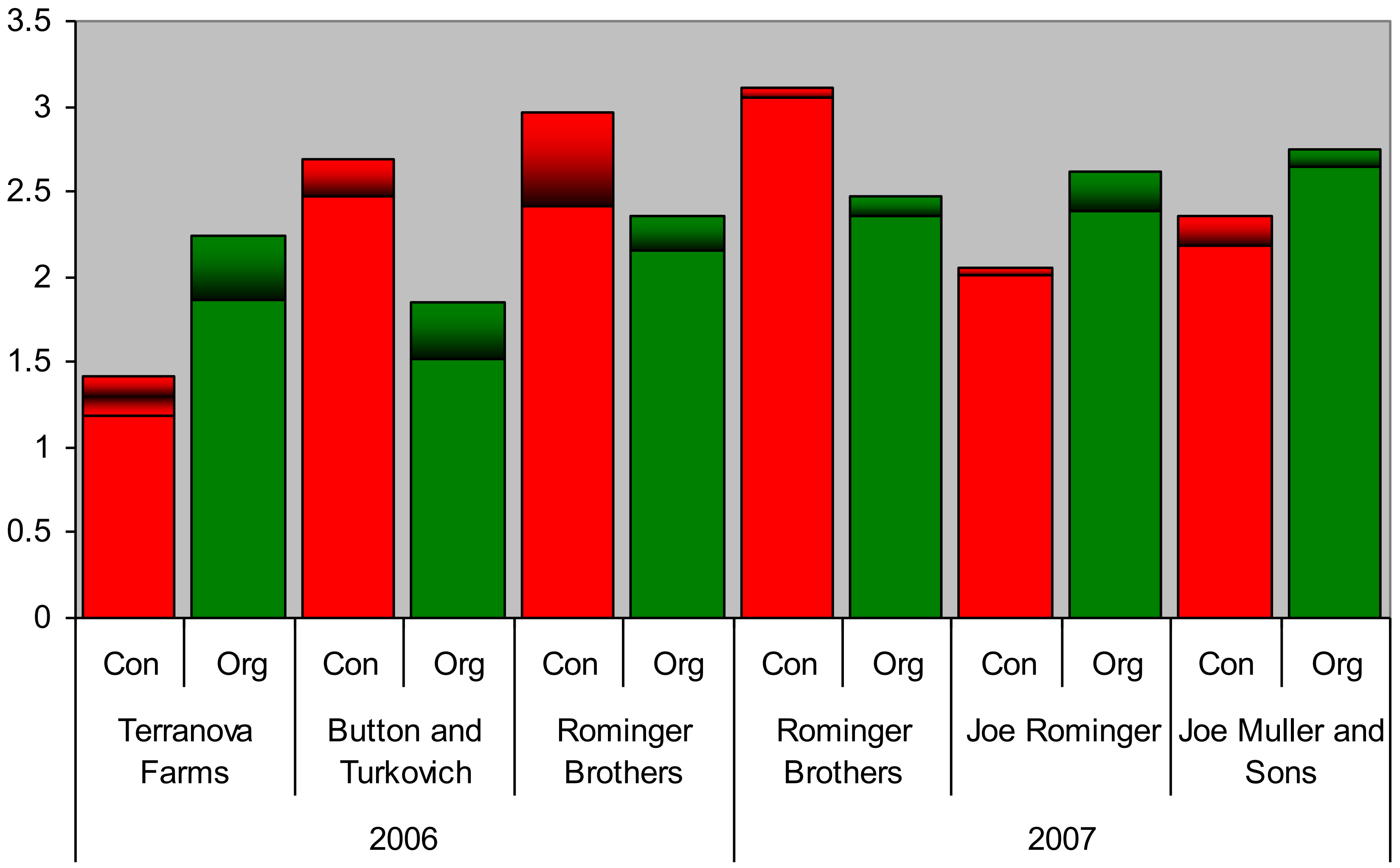


P < 0.01

Hunter *b* values

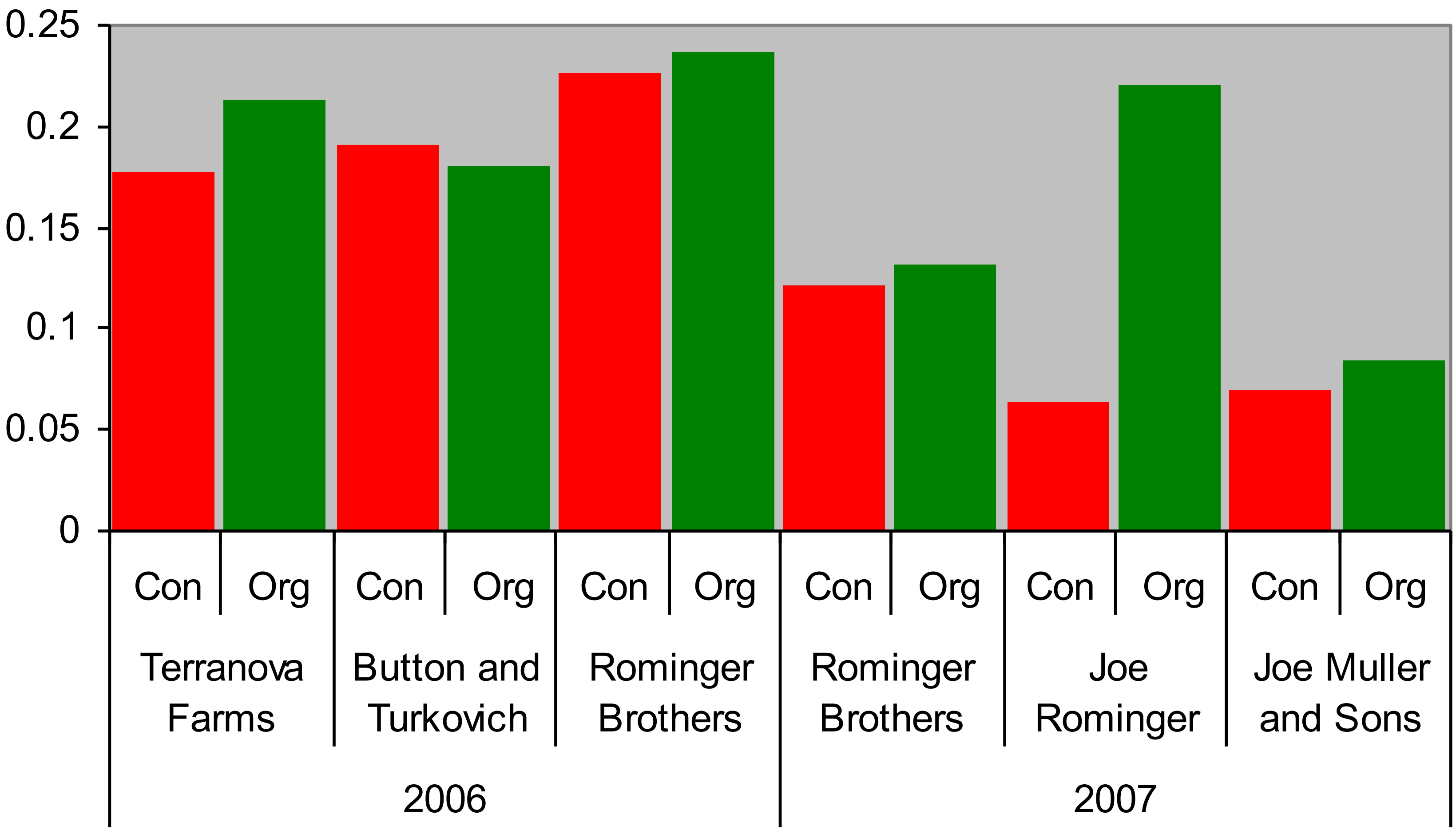


Total Vitamin C



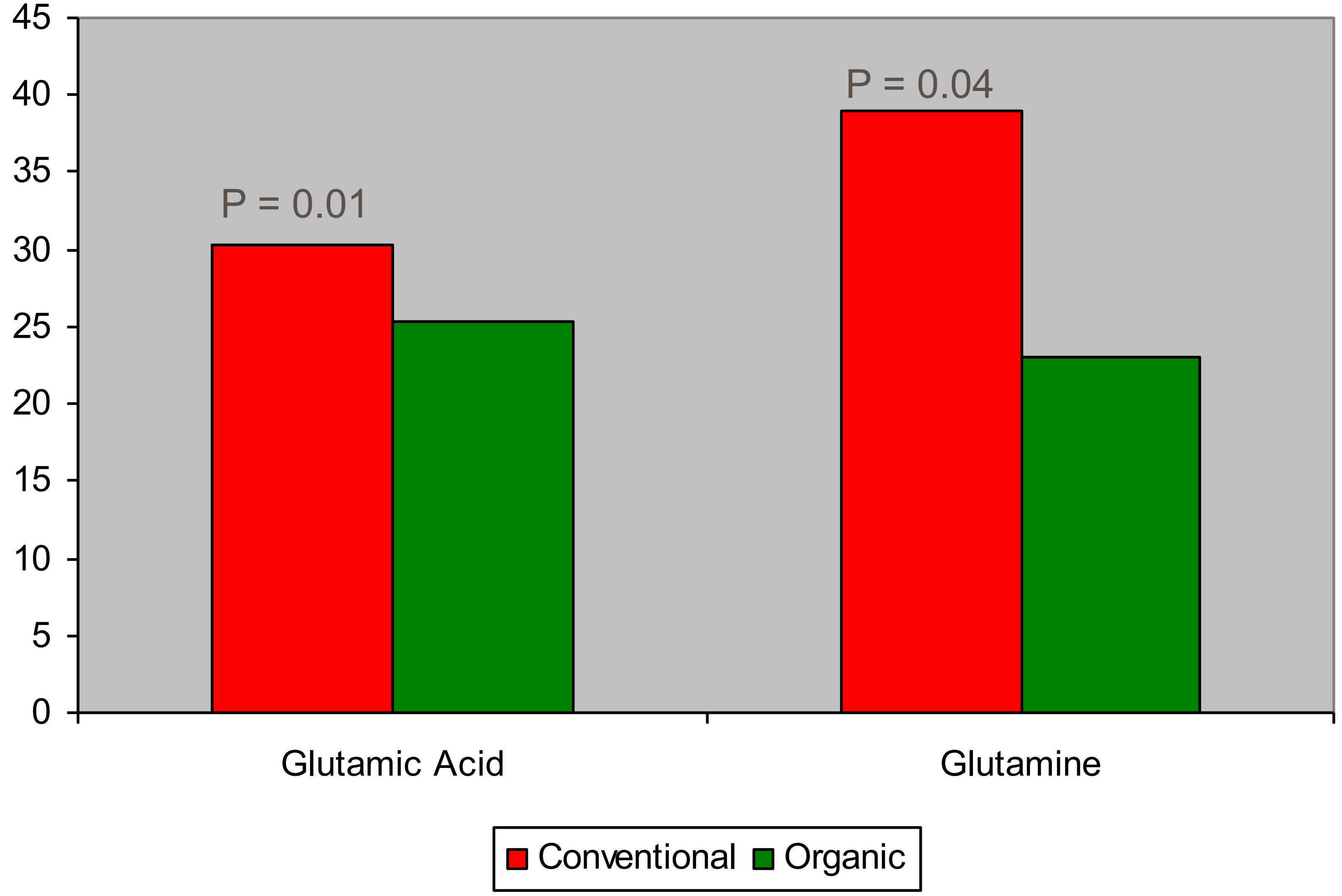
Not significant!

Rutin (g per kg dry weight)



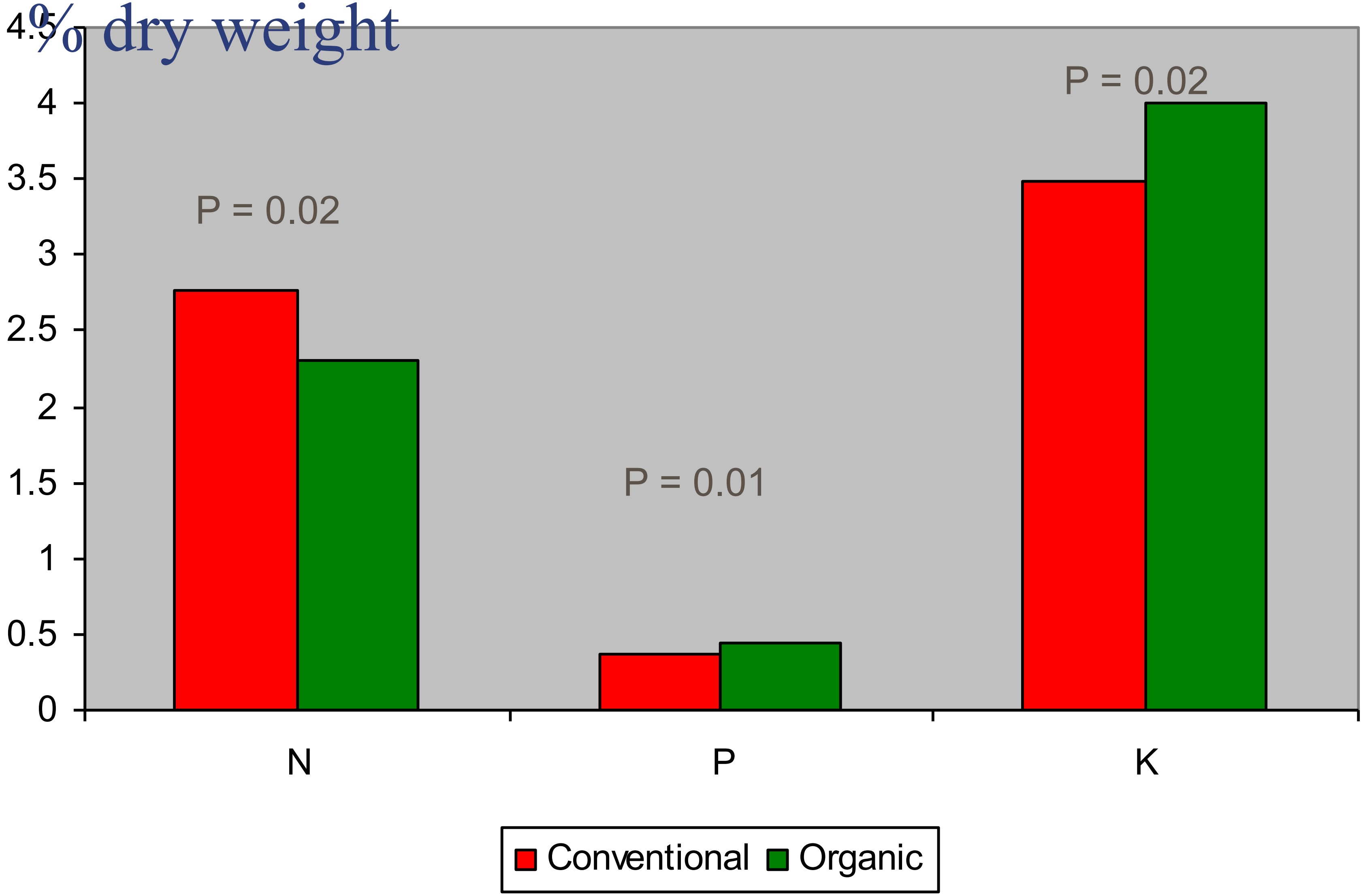
Not significant!

Glutamate and Glutamine

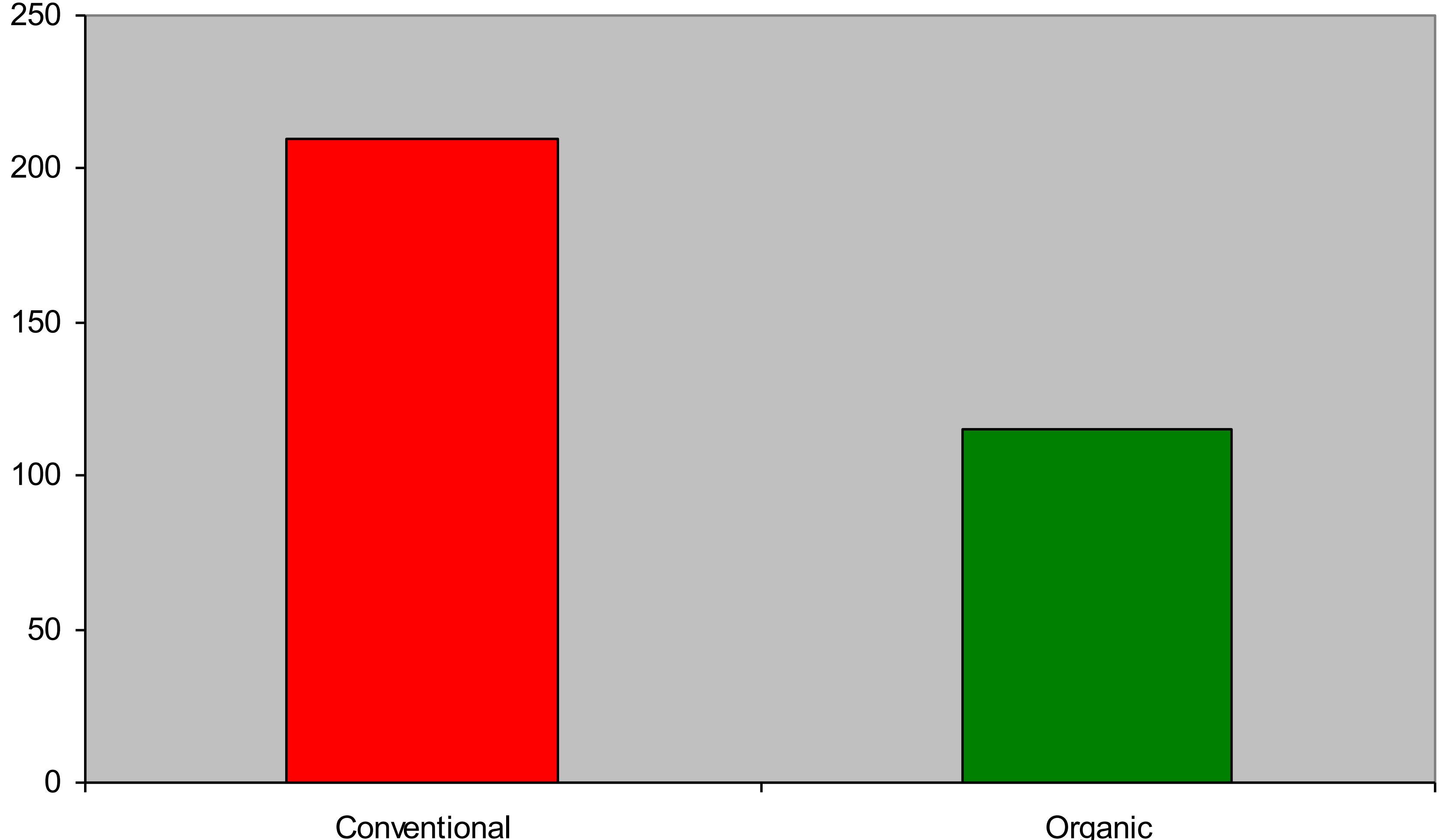


N P K

% dry weight



Ammonium concentration in fruit



P = 0.03

Long Term Research on Agricultural Systems (100 Years – UC Davis)

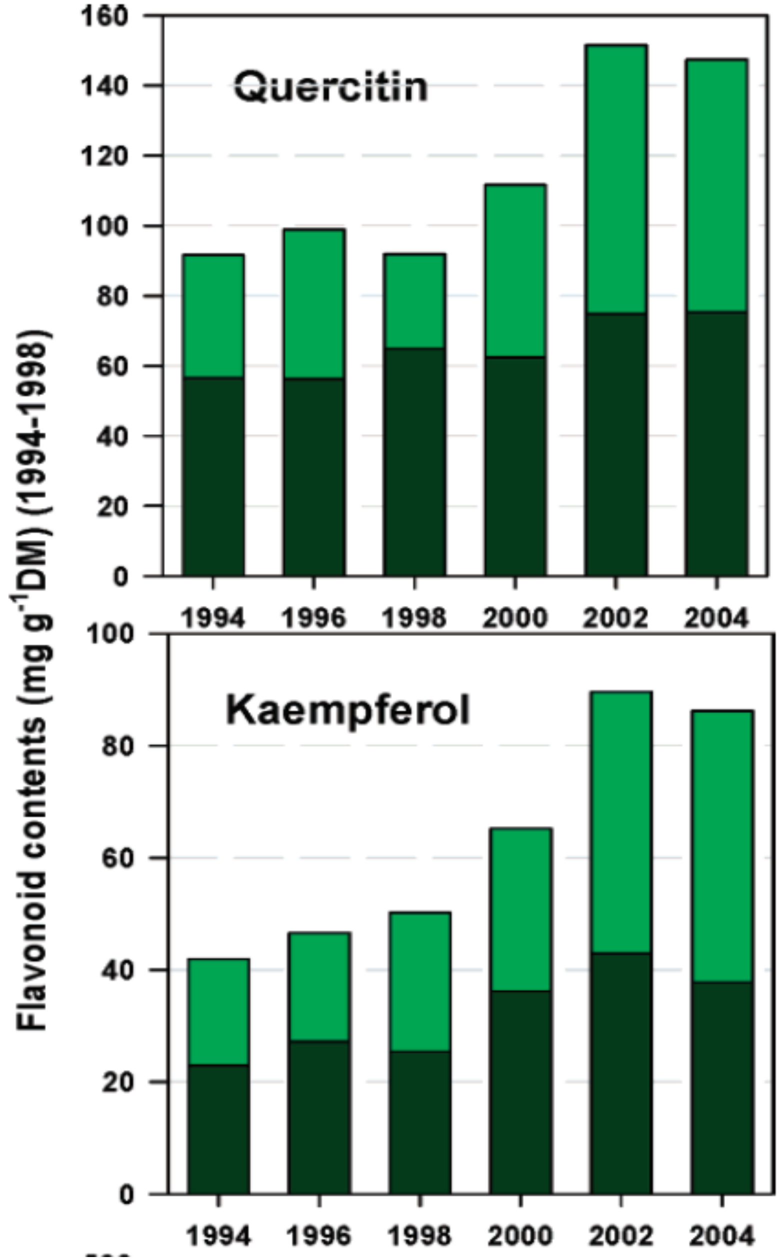
- Organic/conventional tomatoes – dried samples from 1994-2004, flavonoid aglycones

Flavonoid	Conventional mean (SD)	Organic (mg g-1 of DM)	F	p
Quercetin	64.6 (2.49)	115.5 (8.0)	108.16	<0.0001
Naringenin	30.2 (1.57)	39.6 (1.58)	66.36	<0.0001
Kampferol	32.06 (1.94)	63.3 (5.21)	96.64	<0.0001

Mitchell, Barrett, Kaffka, JAFC 2007

Changes in Flavonoid Aglycones over Time. (1994 – 2004)

- Organic significantly higher
- Deterioration in storage



Conclusions – Organic Studies

- Some quality parameters were on average 'better' in organic tomatoes - Why?
- Brix (sugars) and phenolic compounds in particular were higher in organic crops
- Variance often seen grower to grower; year to year
- Drawing conclusions often difficult
  - Variation in experimental design
  - Differences in soils, environment, cultivars etc.
  - Complexity of nutrient and quality development
- Submitted 3 yr proposal to US Dept. Agriculture, but were not funded.

Irrigation Studies

Irrigation Trial Formats

- “Cut back” - irrigation is reduced to something less than full/100% ET prior to typical cut off of water
- “Cut off” - irrigation is stopped a number of days prior to harvest
- Combination - cut back on irrigation for certain period prior to harvest, then use earlier cut off time

Cut Back Effects on Yield and Soluble Solids

	Irrigation	Cut back initiation	ETo over cutback	% of ETo applied	Fruit yield (tons/acre)		Soluble solids	Brix yield
Trial	treatment	(days preharvest)	period (inches)	in cutback period	Total	Mkt.	(º brix)	(tons/acre)
1	grower		10.4	66	77	71	5.8	4.1
	reduced	38		46	75	69	6.0	4.2
					ns	ns	*	ns
2	grower		6.7	27	56	52	6.1	3.2
	reduced	21		17	53	49	6.1	3.0
					**	**	ns	*
3	grower		7.8	57	94	87	5.3	4.6
	reduced	26		33	89	83	5.4	4.5
					ns	ns	ns	ns
4	grower		7.95	46	65	59	5.3	3.1
	reduced	29		0	61	56	5.4	3.0
					ns	ns	ns	ns
5	grower		10.1	32	48	45	5.7	2.6
	reduced	39		20	48	45	5.7	2.6
					ns	ns	ns	ns
6	grower		9.9	67	49	46	5.7	2.6
	reduced	42		33	45	42	5.9	2.5
					ns	*	*	ns
7	grower		11.6	43	60	55	4.7	2.6
	reduced	46		27	58	53	4.8	2.5
					ns	ns	ns	ns
Ave	grower				64	59	5.5	3.3
	reduced				61	57	5.6	3.2
					**	*	**	ns

Cut back reduced yield but improved SSC significantly. (Hartz, 2004)

Irrigation & Peelability Results

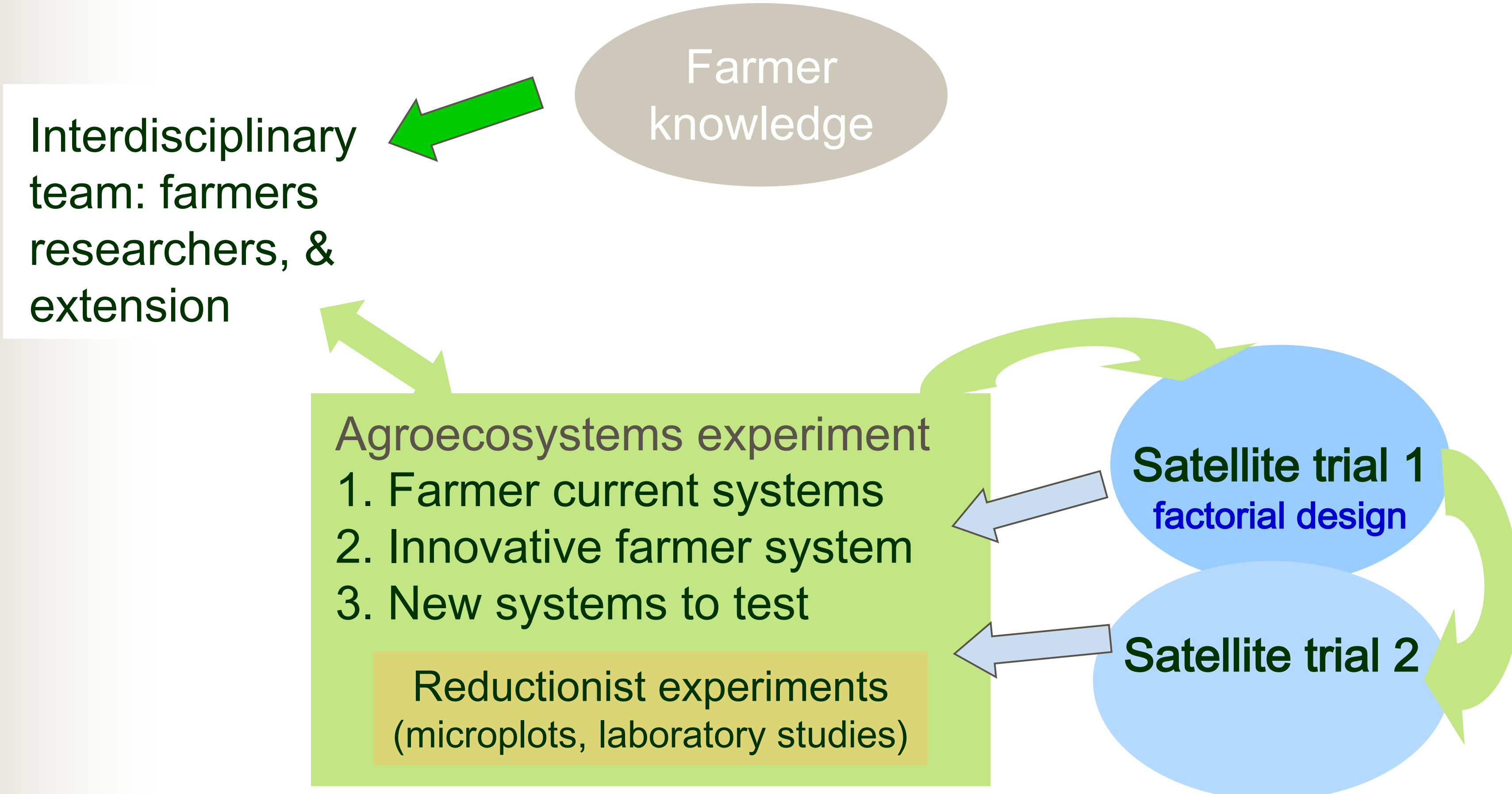
- Drip Trial – "Cut back" and "cut off"
  1. 100% ET, 20 day cut off (min stress)
     - 61.5% decrease in peelability
- 2. 50% ET 55-20 days, 20 day cut off
  - No difference from mean peelability
- 3. 100% ET, 55 day cut-off (max stress)
  - 48% decrease in peelability

On-Farm vs. Lab/Field Experiments

- Realistic, same management practice and constraints
- Robust characterization of agroecosystems
- Can ask broad questions about management, vs. environment or market
- Sites that are closer to a steady-state can be studied

- Minimize confounding sources of variability
- Innovative, promising cropping systems can be included in the experiment
- Usually less costly
- CONTROL!!

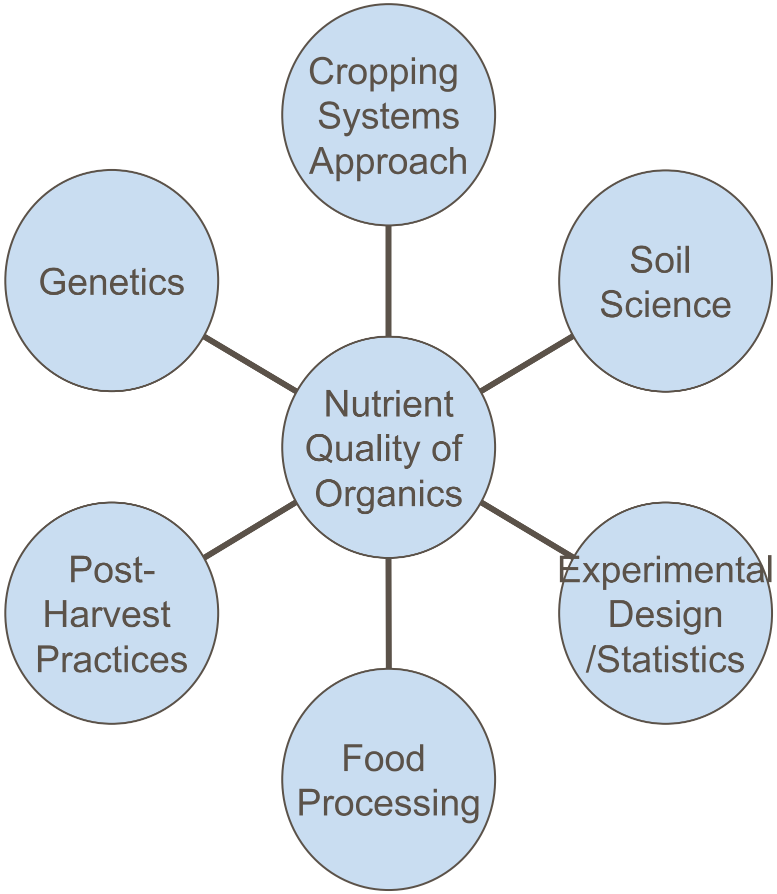
Long-term systems experiment: Design and managment



Drinkwater, modified from Snapp, 2003

Multi-Disciplinary Approach

Understanding effects of cultural practices on food quality



Thanks for your attention!