A two year comparison of several quality and nutritional characteristics in tomatoes and peppers

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Overview

- I. Background
- II. Factors that influence secondary plant metabolites (phenolic antioxidants) in fruits and vegetables
- III. Study design
- IV. Quality measurements

Background

- The public perceives organically grown foods as being “healthier” but there is little scientific evidence to support this perception.
- It is recognized that high-intensity agricultural practices may disrupt the natural production of secondary metabolites involved in plant defense (flavonoids).
  - Flavonoids demonstrate many activities considered beneficial in terms of human health

- ***Does organically produced plant food contain higher levels of defense-related secondary metabolites as compared to conventionally produced plant food?***

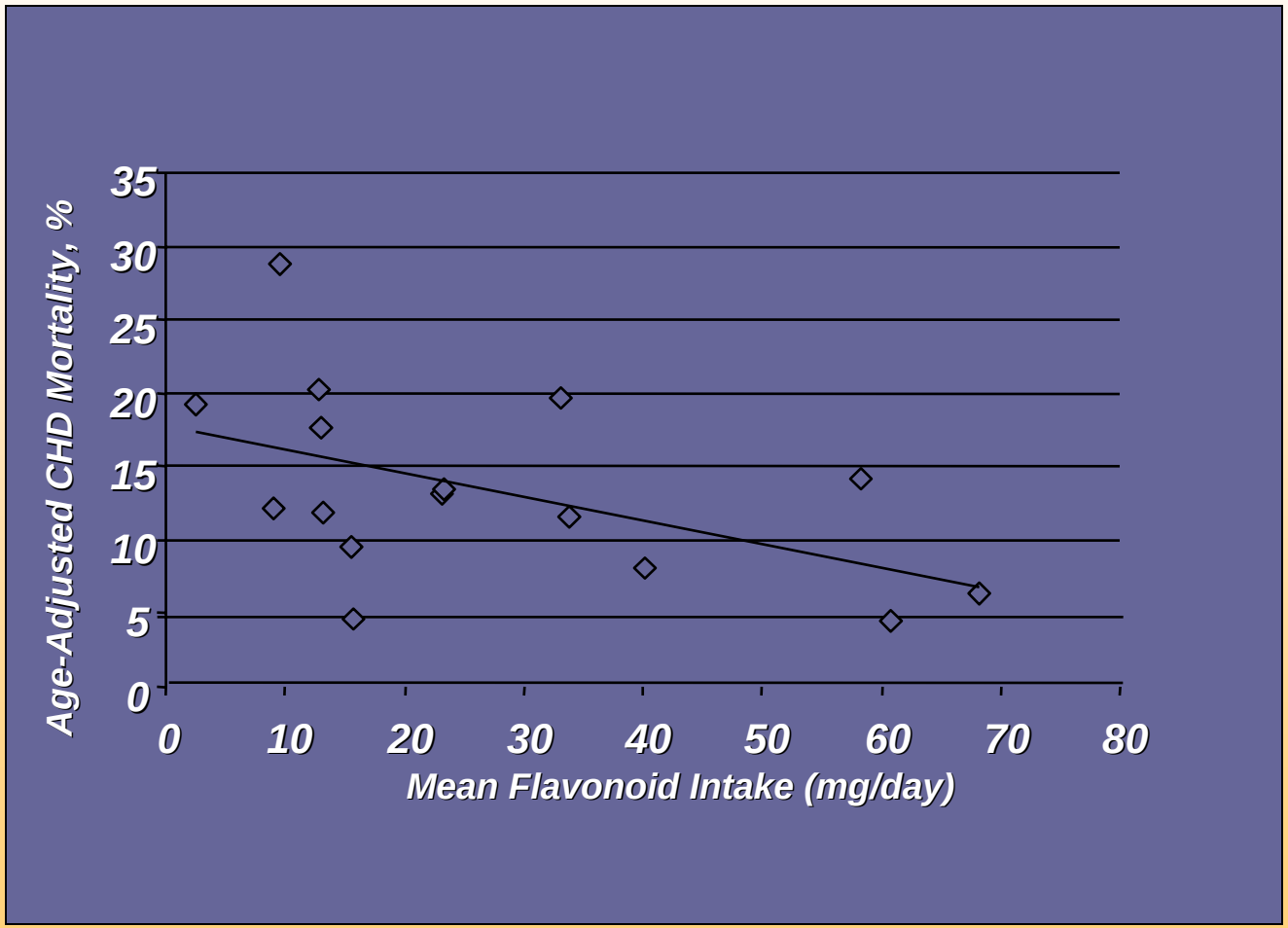
Complexity of the Systems

- Comparisons of organic and conventional foods are difficult to interpret for many reasons:
  - Difficulty in selecting farms and fields that represent the cultivation practices
  - Farming systems are dynamic environments with regional variation
    - Difficulty in matching soil, irrigation, minerals, climate, etc
  - No definition of “conventional” farming
    - Evolved in response to technological developments in mechanization/tillage, monoculture, synthetic fertilizer, chemical pest and weed control, and breeding
    - Organic is “defined” but conditions vary dependent upon season, crop, region, pest pressures and farm philosophies

Phytochemicals

- Phenolic compounds
  Flavonoids
  Phenolic acids
- Carotenoids
  Lycopene
  Beta-carotene
  Xanthophylls
- Monoterpenes
  Limonene
- Sulfur compounds
  Glucosinolates
  Indoles
  Allicin

Flavonoid Intake & Risk of CHD Mortality

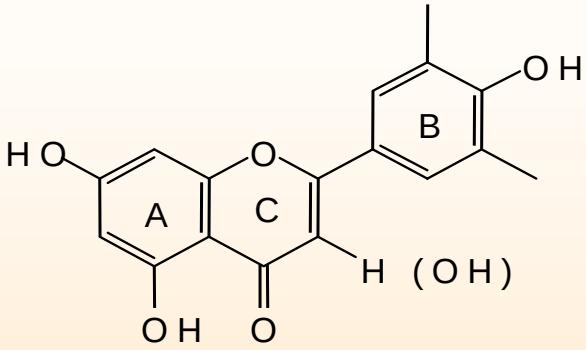


Hertog et al. Arch Intern Med 1995, 155: 381

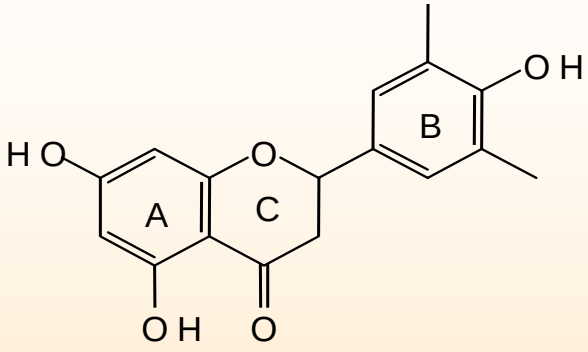
Favonoid Activity

- This inverse association is thought to be due to a number of factors including flavonoid-induced changes in: oxidant defense mechanisms, platelet function and vascular reactivity
- Potent Antioxidants: metal chelation, hydrogen donation and radical scavenging activity
- Improve Blood Vessel Strength
  - (Szent-Gyorgyi, *Nature 138:798;1936, Nature 137:27;1936*)
- Enzyme Inhibition/Activaton:
  - Inhibits enzymes that can generate free radicals and convert noncarcinogens to carcinogens (cytochrome P450 reductases), lipoxygenases (quercetin), xanthine oxidase, cyclooxygenase
  - Activation of phase II detoxification enzymes: glutathione S-transferases, quinone reductase, UDP glucuronyltransferase

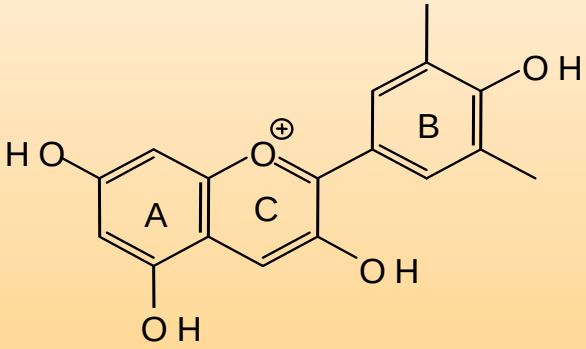
Flavonoid Structure



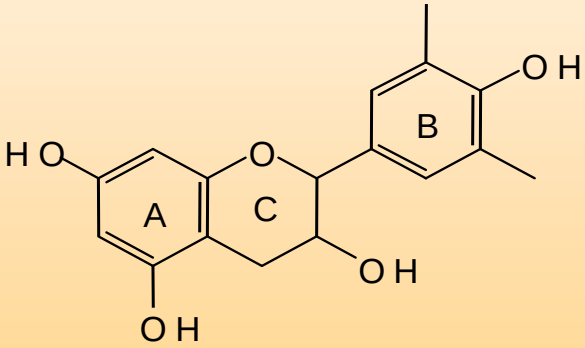
Flavone (Flavonol)



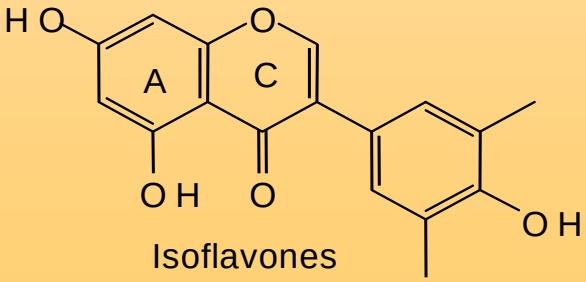
Flavanones



Anthocyanidins

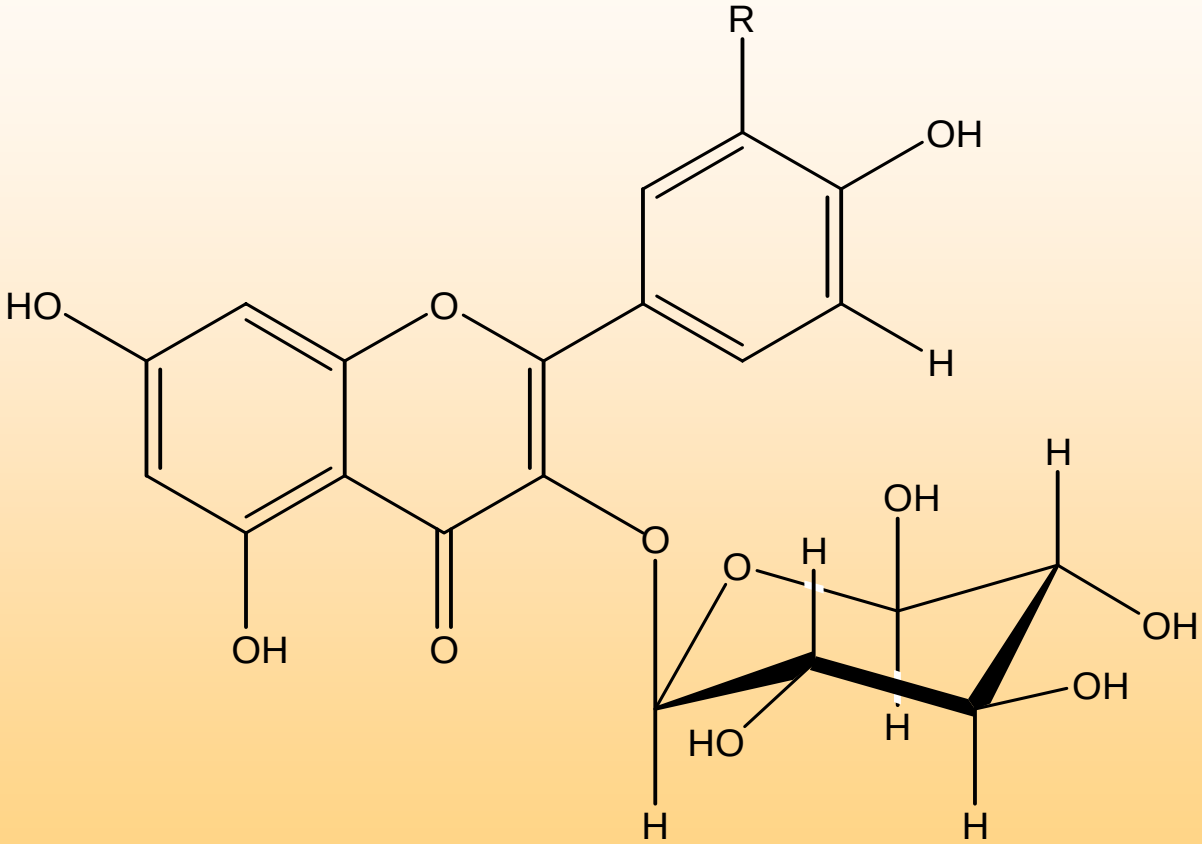


Favan-3-ols



Isoflavones

Quercetin & Kaempferol (Flavonols)



R = OH;Quercetin
R = H; Kaempferol

3 Hydroxyl group is generally glycosylated

II. Factor that Influence phenolic antioxidants in plants

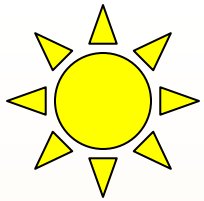
- Phenolic antioxidants are secondary metabolites that function primarily in the defense of the plants
- *Functions are varied*:
  - UV screens / antioxidants
  - Protection from certain types of herbivory (anti-feedants)
  - Protection from pathogen attack
  - Function in wound healing
  - Plant pigments (attract pollinators)

Levels will reflect these dynamics

Pre-Harvest Factor that Influence Antioxidants in Fruit and Vegetables

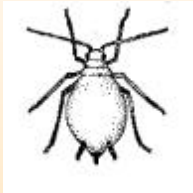
- Endogenous Factors
  - Genotype (i.e. cultivar or variety)
  - Maturity at harvest
  - Tissue distribution
- Exogenous Factors
  - Climate / UV exposure / soil type
  - Pathogen stress
  - Animal/insect herbivory
  - Soil micro-environment

} Influenced by Agronomic practices



UV Light
anthocyanidins
flavonols/flavones
psoralens

Wounding
chlorogenic acid
coumarins
lignin



Pathogen Attack
isoflavones
coumarins
flavonols
stilbenes

Low Nitrogen
flavonoids,
isoflavonoids

Low Iron
Phenolic acids

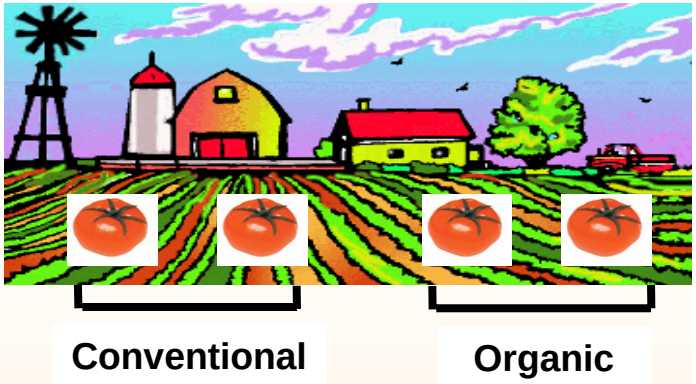
Low Phosphate
anthocyanidins

R.A., Dixon and N. L. Paiva, Stress-Induced Phenylpropanoid Metabolism. The Plant Cell, 1995, 7; 1085-97

Post-harvest Factor that Influence Antioxidants in Fruit and Vegetables

- Storage
  - Time
  - Temperature
  - Relative humidity
- Duration to Retail Sale
- Post-Harvest Processing
  - Wounding
  - Freezing
  - Freeze-drying
  - Canning, etc

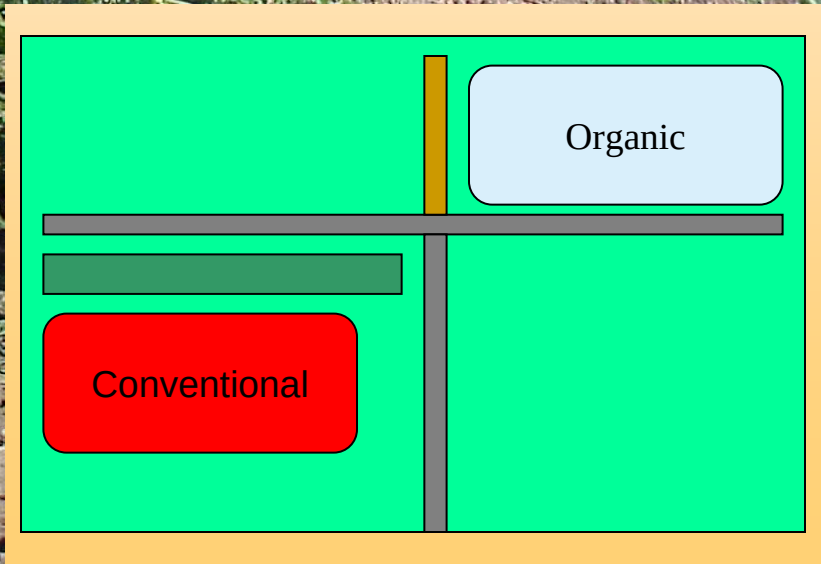
III. Study Design



- **Fields:**
  - Matched certified organic (2002) and conventional fields
  - The fields are separated by a road, fruit trees, Tamarisk trees.
  - Approximately 350 feet (107 meters) apart.
  - Water source and system were the same
  - Plants were grown using a randomized split-block design
  - Primary plants were sampled
- **Treatments:**
  - Organic plants received fertilization from cover crops and cow manure.
  - Conventional crops received 16-48-12 (nitrogen-phosphorus-potassium) liquid fertilizer and ammonium sulfate.
  - Pyrellin and permithrin (aphids) and diazinon (whitefly in peppers) were applied to conventional plots

Windbreak

Conventional fields



Cultivars and Measurements

- **Cultivars:**
  - Tomatoes (Lycopersicon esculentum sp. Burbank and Ropreco),
  - Green peppers (Capsicum annuum sp. Cal Wonder and Excaliber)
- **1. Baseline Soil Measurements**
- **2. Analytical Measurements**
  - A. Percentage of soluble solids
  - B. Total phenolics
  - C. Ascorbic acid
  - D. Aglycones of quercetin, luteolin and kaempferol

Baseline Measurements

- **Soil Sampling**: Soil pH, cation exchange capacity, base saturation, minerals (Ca, P, K, Mg, B, Zn, Fe, Mn, Cu), total Kejldal nitrogen (TKN), ammonia, and nitrate.
  - Soil pH, cation exchange capacity were similar
  - Differences were found in minerals, TKN, ammonium and nitrate with levels being 0.5-3x higher in organic soils
- **Microbiological testing:**
  - Both soils displayed active and total bacterial and fungal biomasses in desired ranges
  - Protozoa numbers and nematode diversity were lower than optimal in conventional soils

Harvest & Processing
UC Davis
Processing Facility

Washed
Sorted by size and color
Sliced and vacuum packaged
Sub-samples were freeze-dried and stored at –80 C

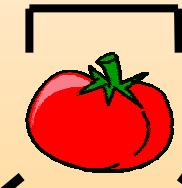
Sliced and frozen at -40 ºC

Thaw & Homogenize

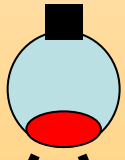
Total Phenolics — Modified Singleton & Rossi (1967) Method

Freeze Dry

Flavonoid Analysis (flavonoid aglycones)

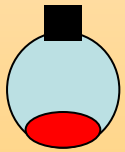


Freeze Dried Tomatoes

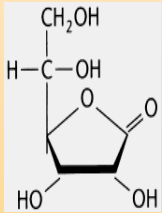


62.5% MeOH, 1.2N HCl

4 hours @100C



Vitamin C — Modified Lee and Coates (1987) HPLC Method

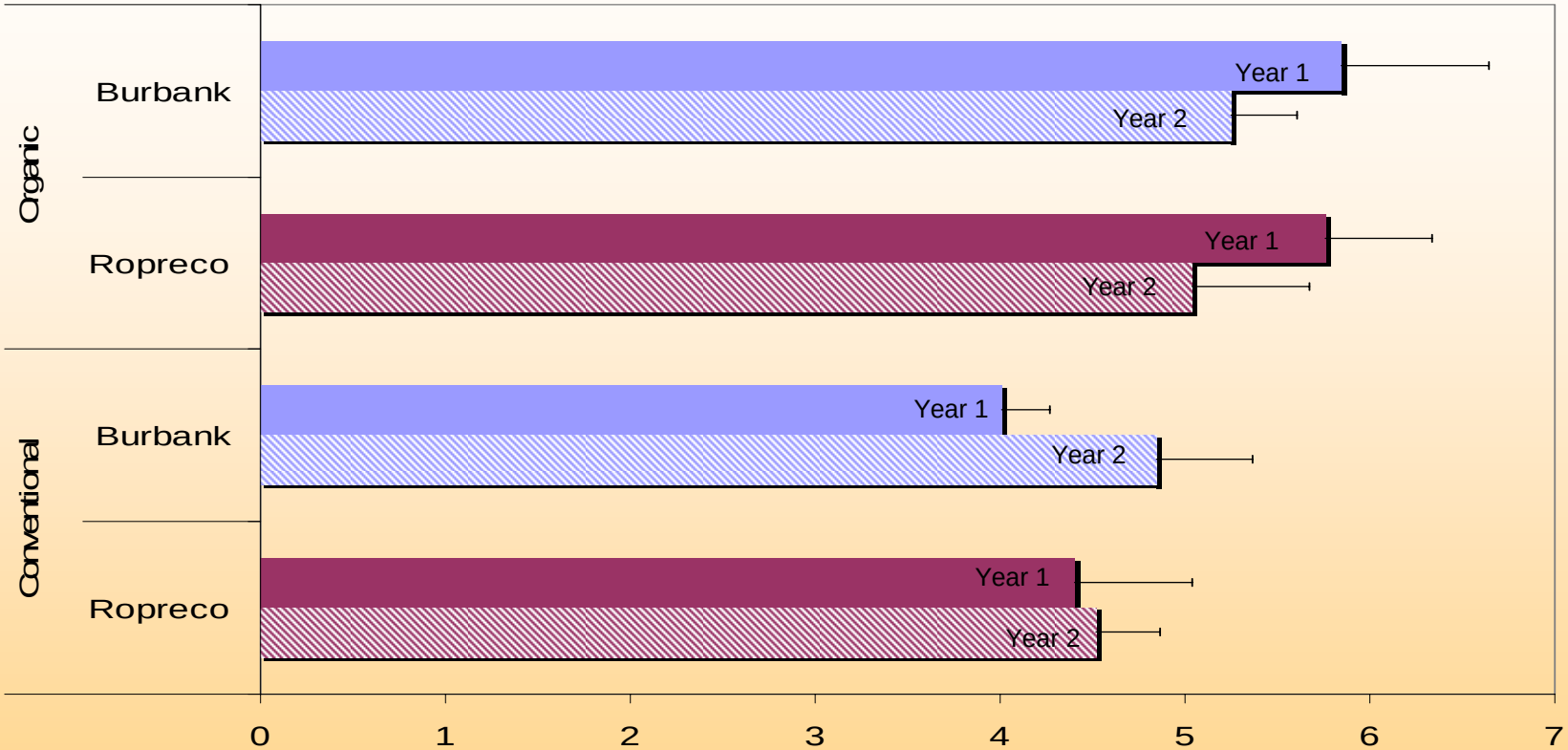


Percent Soluble Solids

RFM 80 Refractometer (Bellingam + Stanley)

Based upon Merken and Beecher (2000)

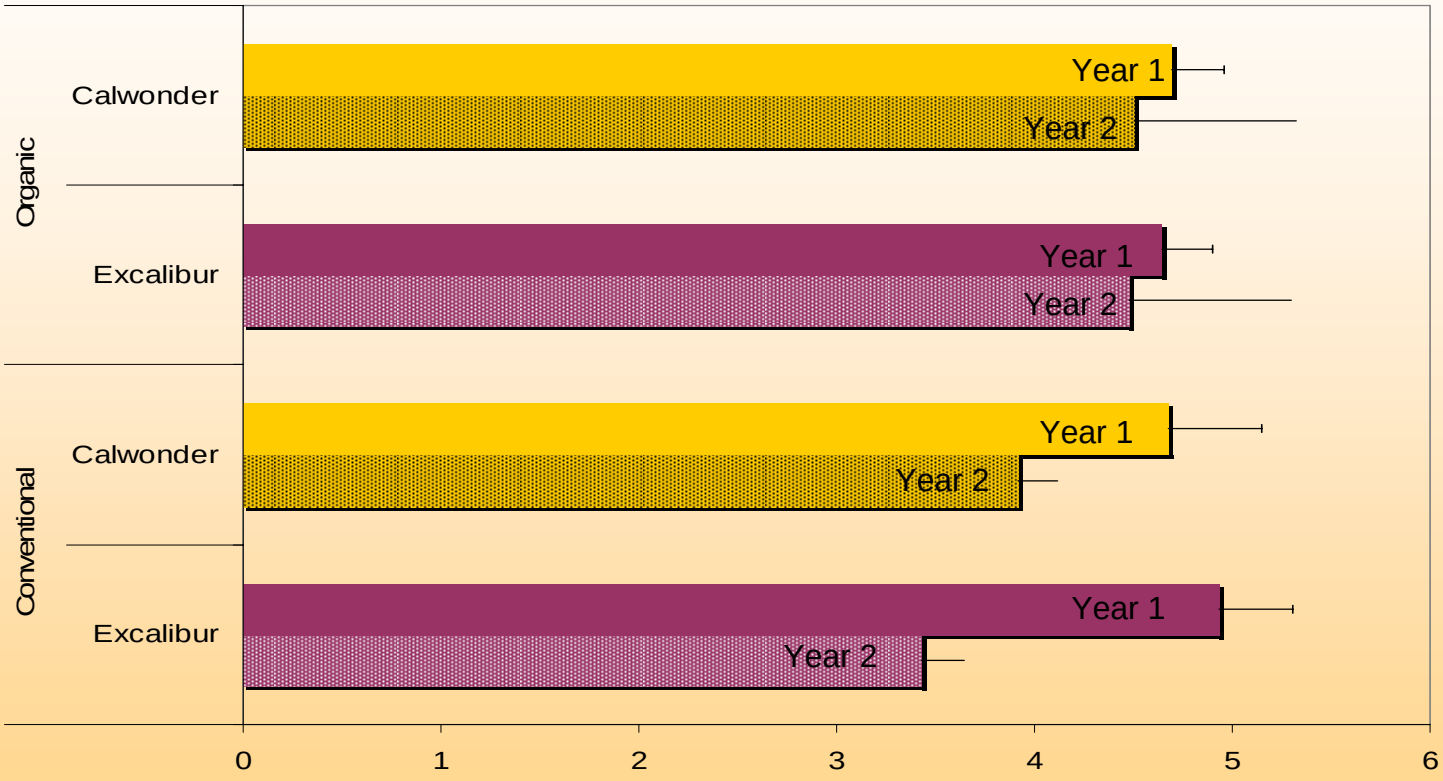
A. Comparison Percent Soluble Solids in Tomatoes



Difference significant at p < 0.0001

Year 1: Significant difference between agricultural practices both cultivars
Year 2: Trend of higher levels in organic cultivation

Comparison of Percent Soluble Solids in Peppers

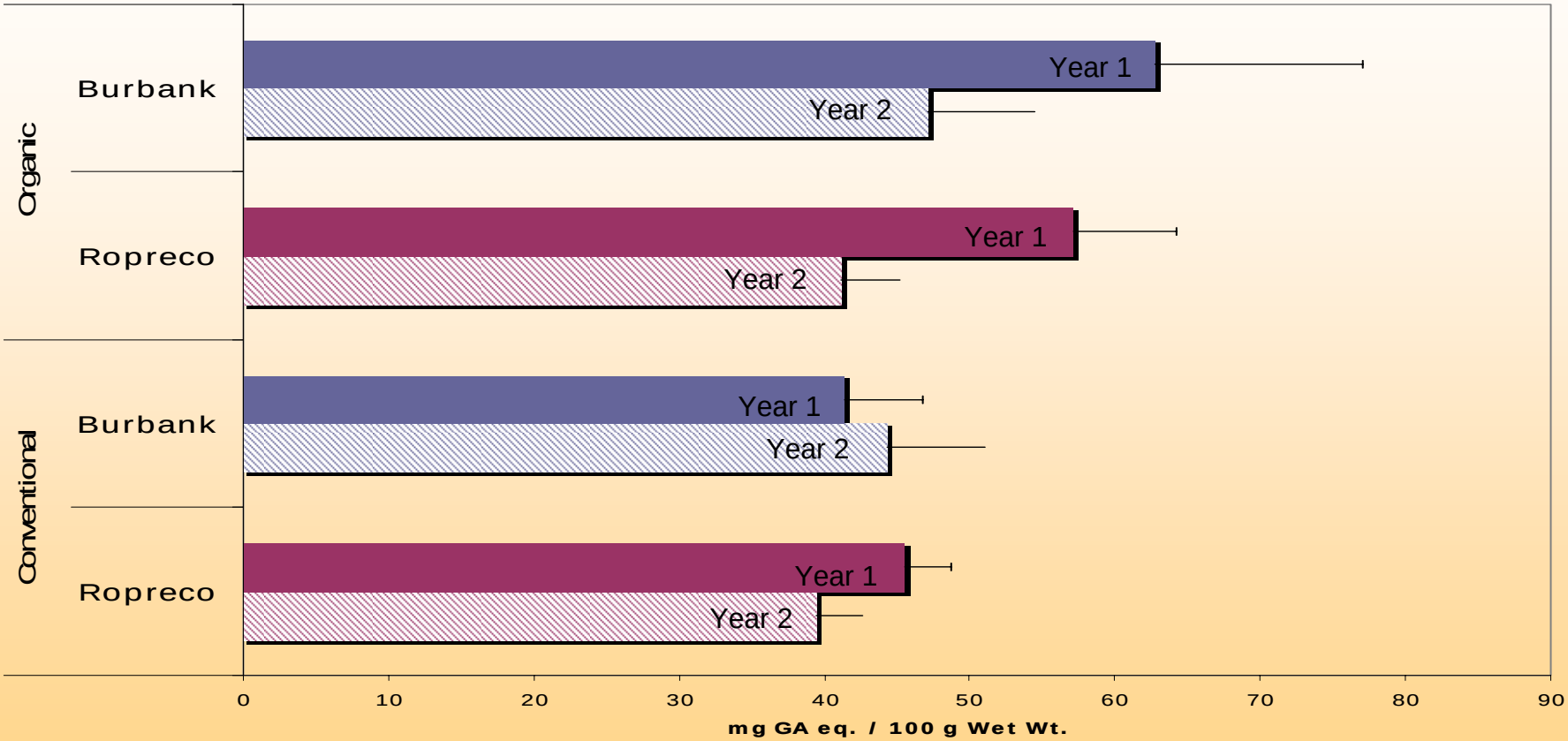


 # Difference significant at p < 0.0001

Year 1: No significant differences in cultivars or between cultural practices

Year 2: Significant interaction between years in conventional cultivation and cultural practices

B. Comparison of Total Phenolics in Tomatoes

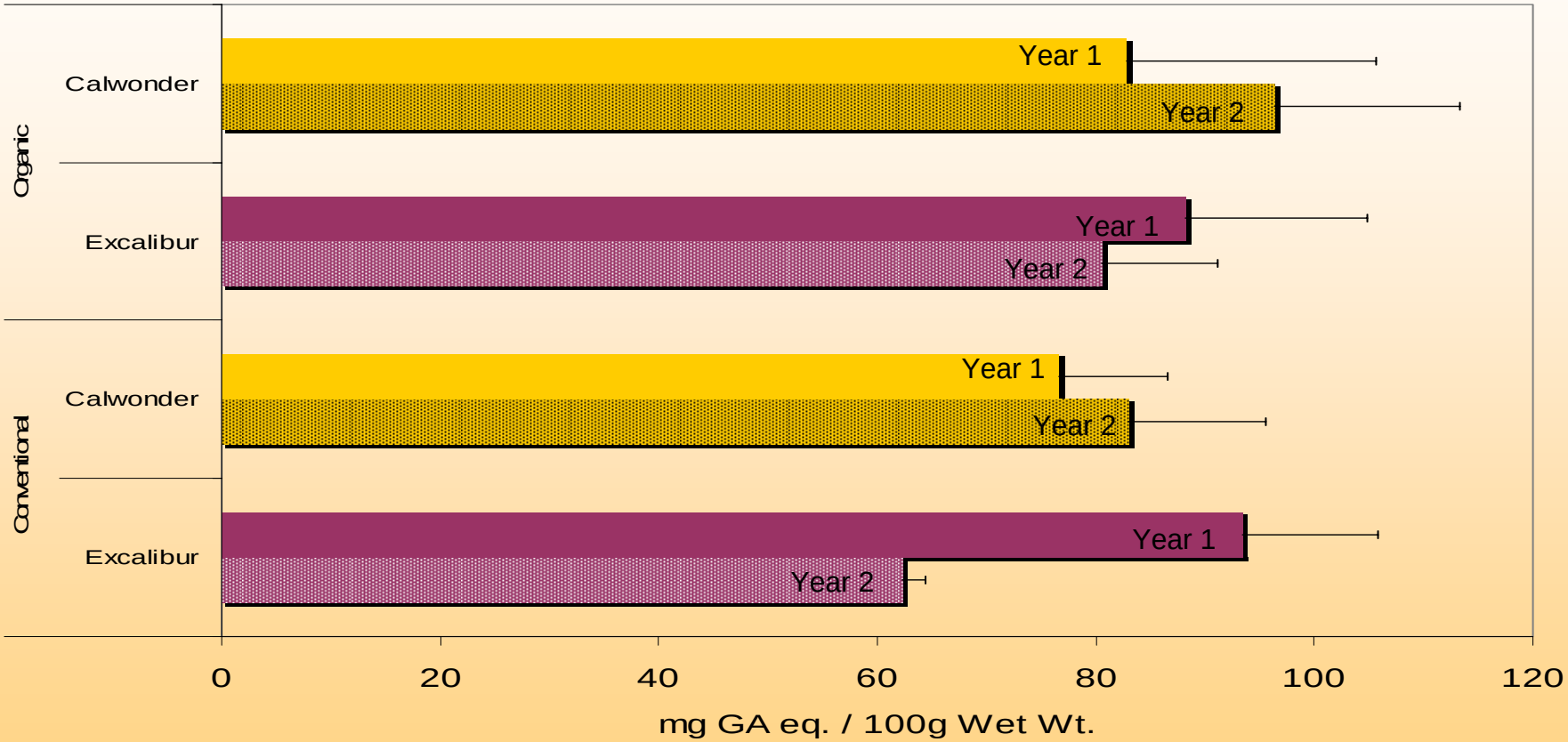


Difference significant at $p < 0.0001$

Year 1: Significant difference between agricultural practices

Year 2: Significant interaction between years in organic cultivation both cultivars

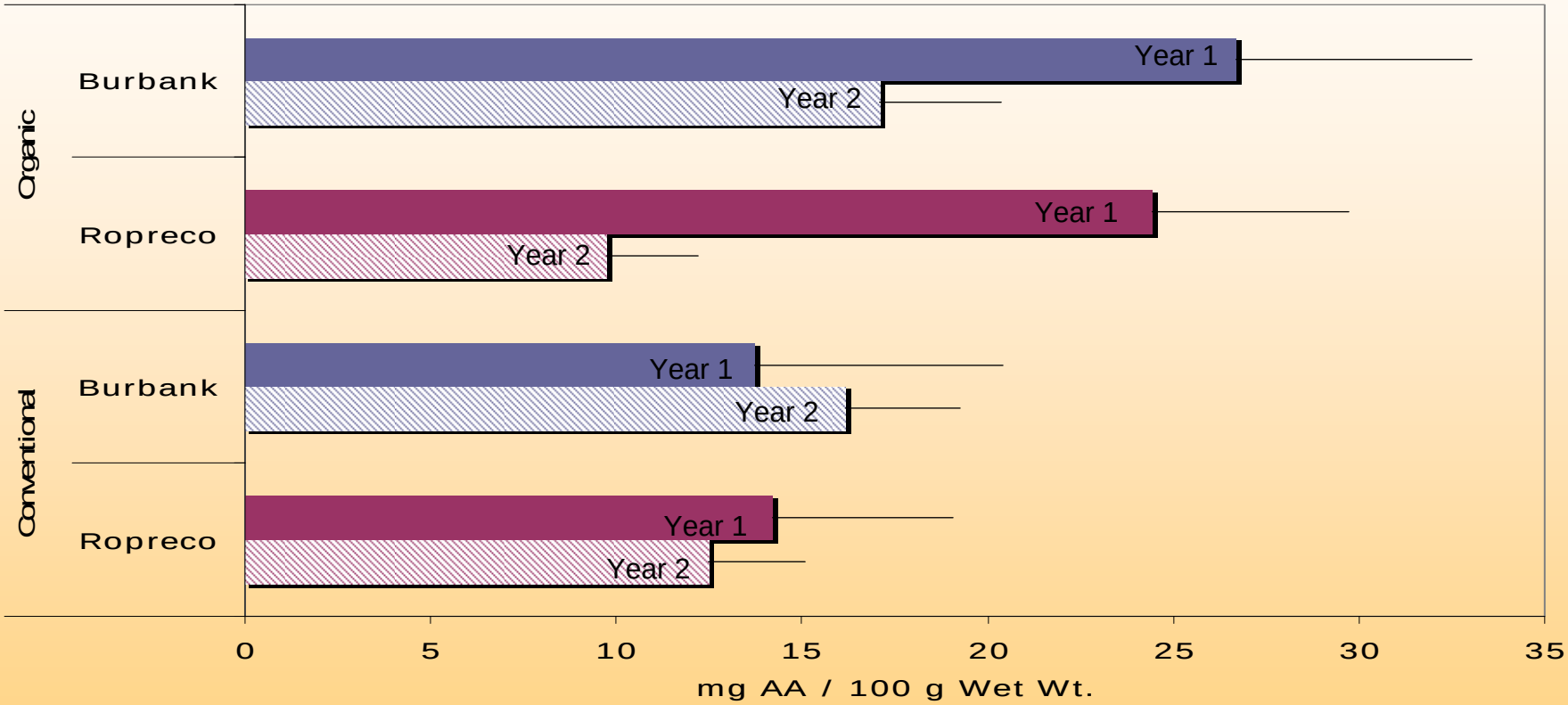
B. Comparison of Total Phenolics Peppers



Year 1: No significant difference in cultivars or between cultural practices

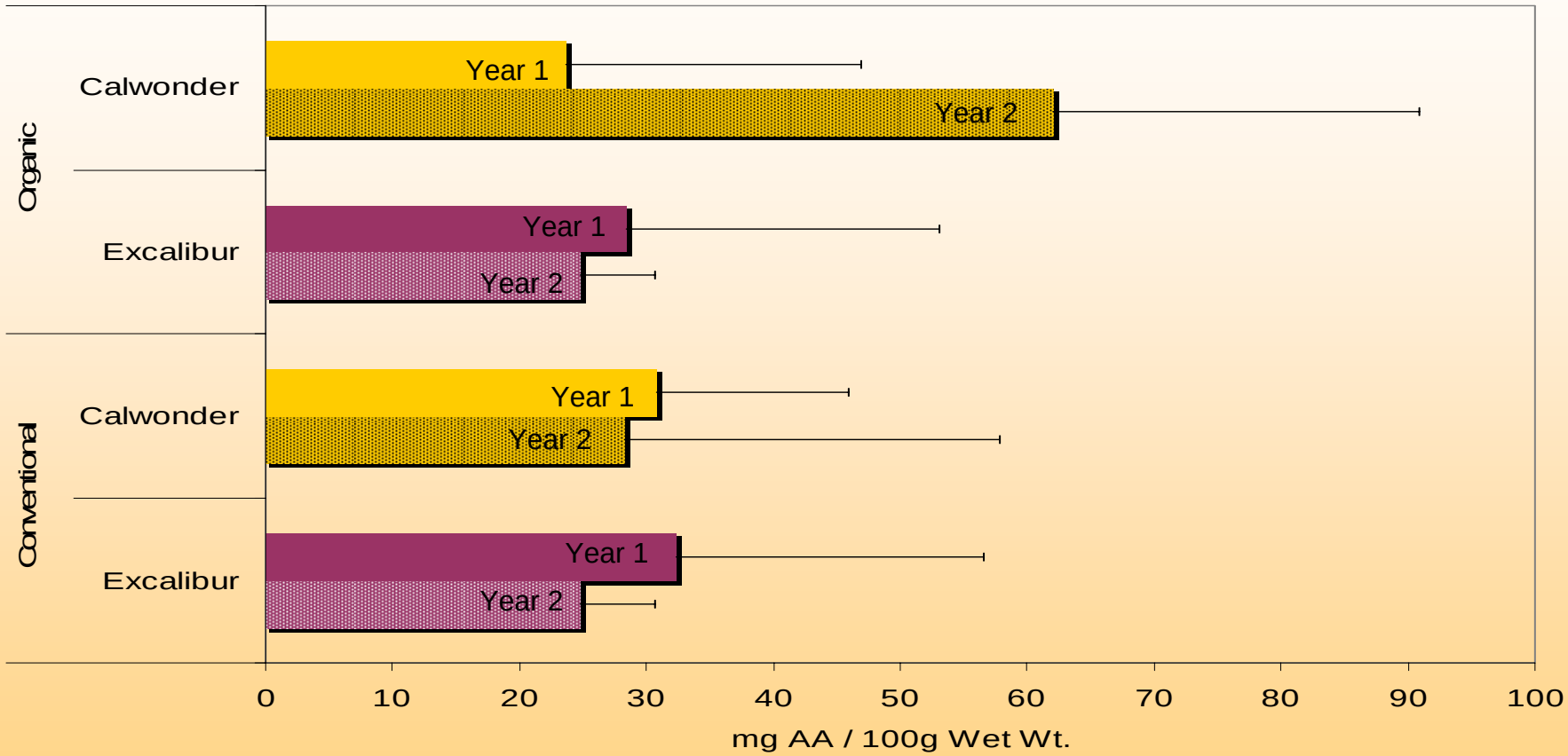
Year 2: Significant interaction between years in conventional cultivation and cultural practices both cultivars

C. Comparison of Ascorbic Acid in Tomatoes



Year 1: Significant difference between agricultural practices both cultivars
Year 2: Significant interaction between years in organic cultivation

Comparison of Ascorbic Acid in Peppers



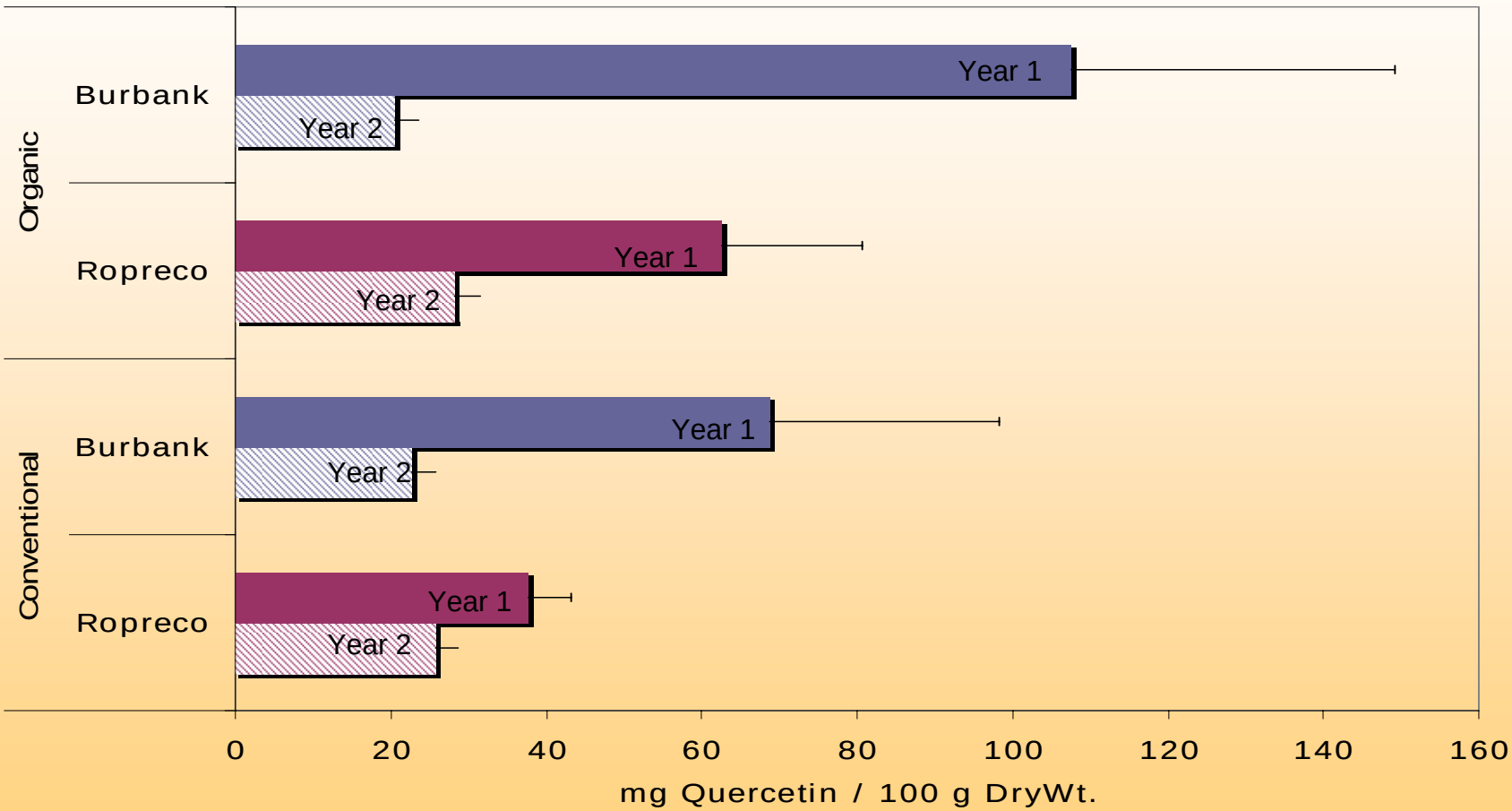
Year 1: No significant difference between agricultural practices both cultivars

Year 2: Significant interaction between years for organic cultivation for Cal Wonder and between cultivation for Cal Wonder

D. Comparison of Flavonoid Aglycones

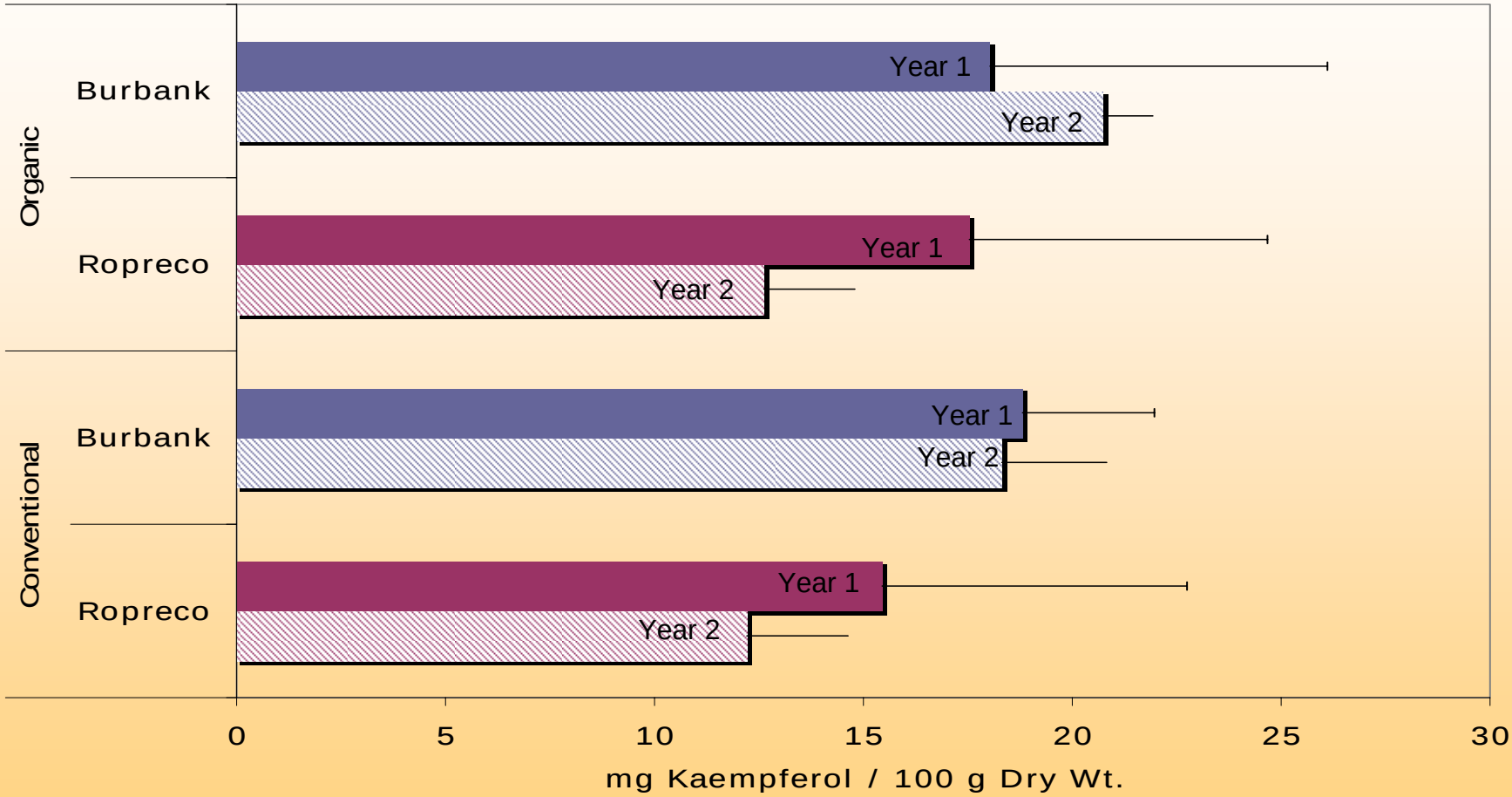
- Standards for range of flavonoid glycosides
- Optimize conditions for hydrolysis of the flavonoids in each matrix
- Rate will depend upon type of sugars and/or the matrix
- Recoveries were determined using luteolin (tomatoes) and morin (peppers)
- Values are based upon external calibration

D. Comparison of Quercetin in Tomatoes



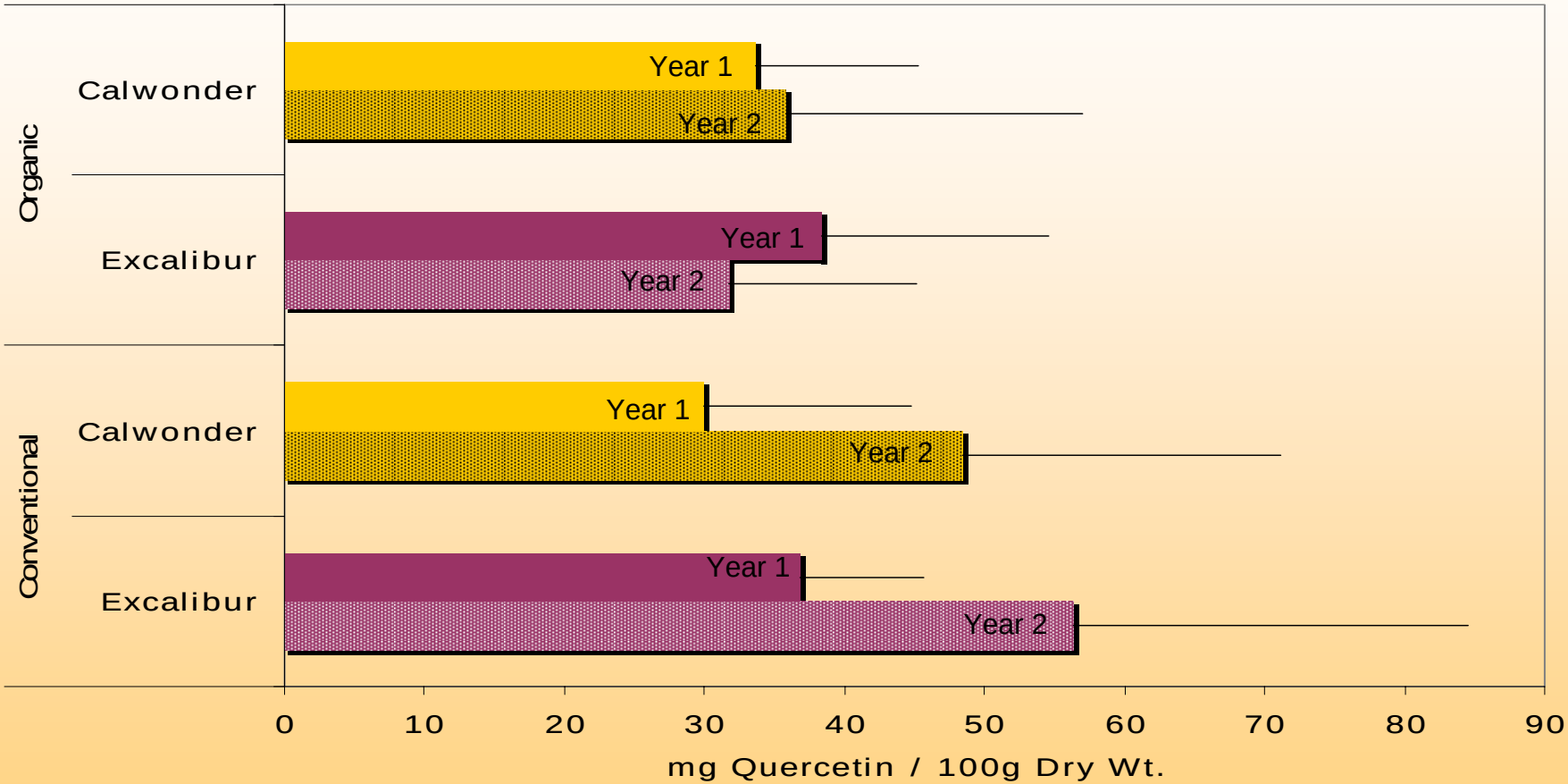
Year 1: Significant difference between agricultural practices both cultivars
Year 2: Significant interaction between years for both cultivars

Comparison of Kaempferol in Tomatoes



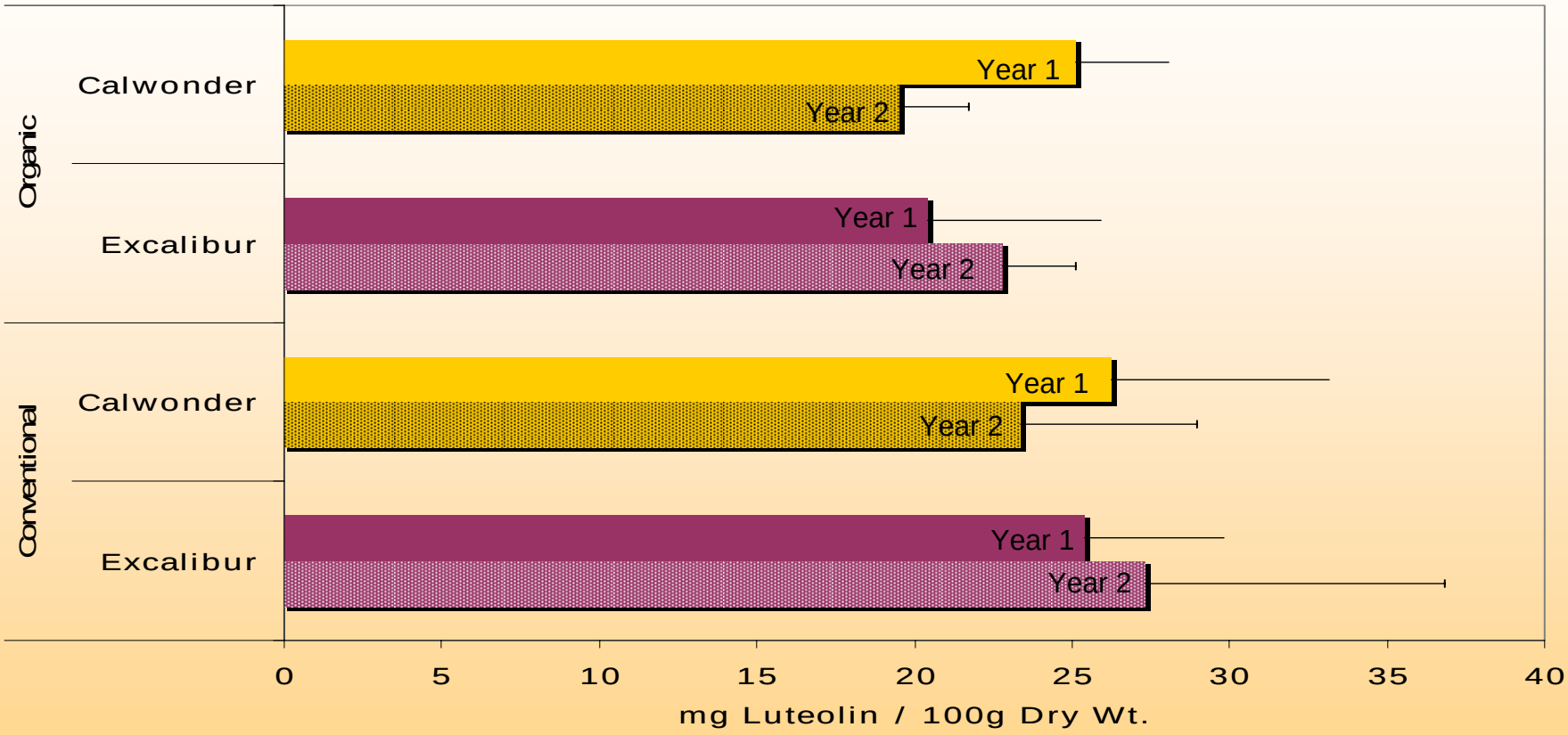
Year 1: No significant difference between agricultural practices both cultivars
Year 2: Significant interaction between years for Ropreco

E. Comparison of Quercetin in Peppers



Year 1: No significant difference between agricultural practices both cultivars
Year 2: Significant interaction between years for Conventional cultivation

Comparison of Luteolin in Peppers



Year 1: No significant difference between agricultural practices both cultivars
Year 2: No significant difference between agricultural practices both cultivars

So What Does This All Really Mean?

- Replication is critical for determining trend in nutritional and quality characteristics in produce
- Overall 2-year trend of higher levels of soluble solids, total phenolics, vitamin C and quercetin in organic tomatoes as compared to their conventional counterparts
  - Primarily from values obtained in the first year crop
- Overall 2-year trend of higher levels of soluble solids, total phenolics and vitamin C in organic peppers as compared to their conventional counterparts
  - Quercetin levels were higher in conventional bell peppers in year 2
  - Cultivation practices had less of an effect on the levels of soluble solids, total phenolics, vitamin C or flavonoid aglycones in bell peppers as compared to tomatoes

Support

- MasterFoods (Linh Bui, Howard Shapiro, John Hammerstone)
- Seeds of Change (Erica Renaud)
- Organic Farming Research Foundation