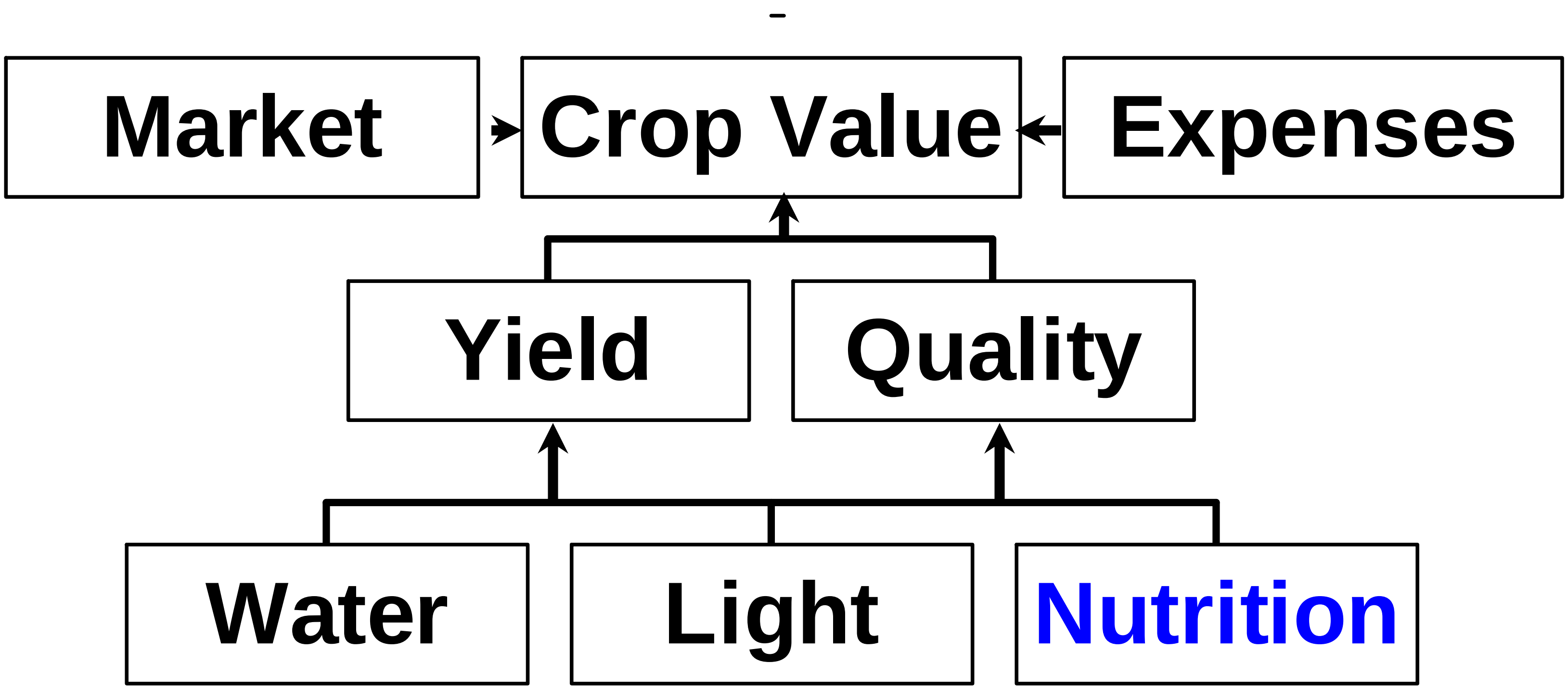
Mineral Nutrition & Management

Productivity & Profitability



Topics

- Nutrient cycling & utilization
- Roots & nutrient uptake
- Nitrogen cycle & biological activity
- Cover crops & mulches
- Plant nutrient status
- Calcium & fruit quality
- Nutrient requirements & deficiencies
- Nutrient applications
- Organic nutrient management

Nutrient Cycling in Perennial Fruit Crops

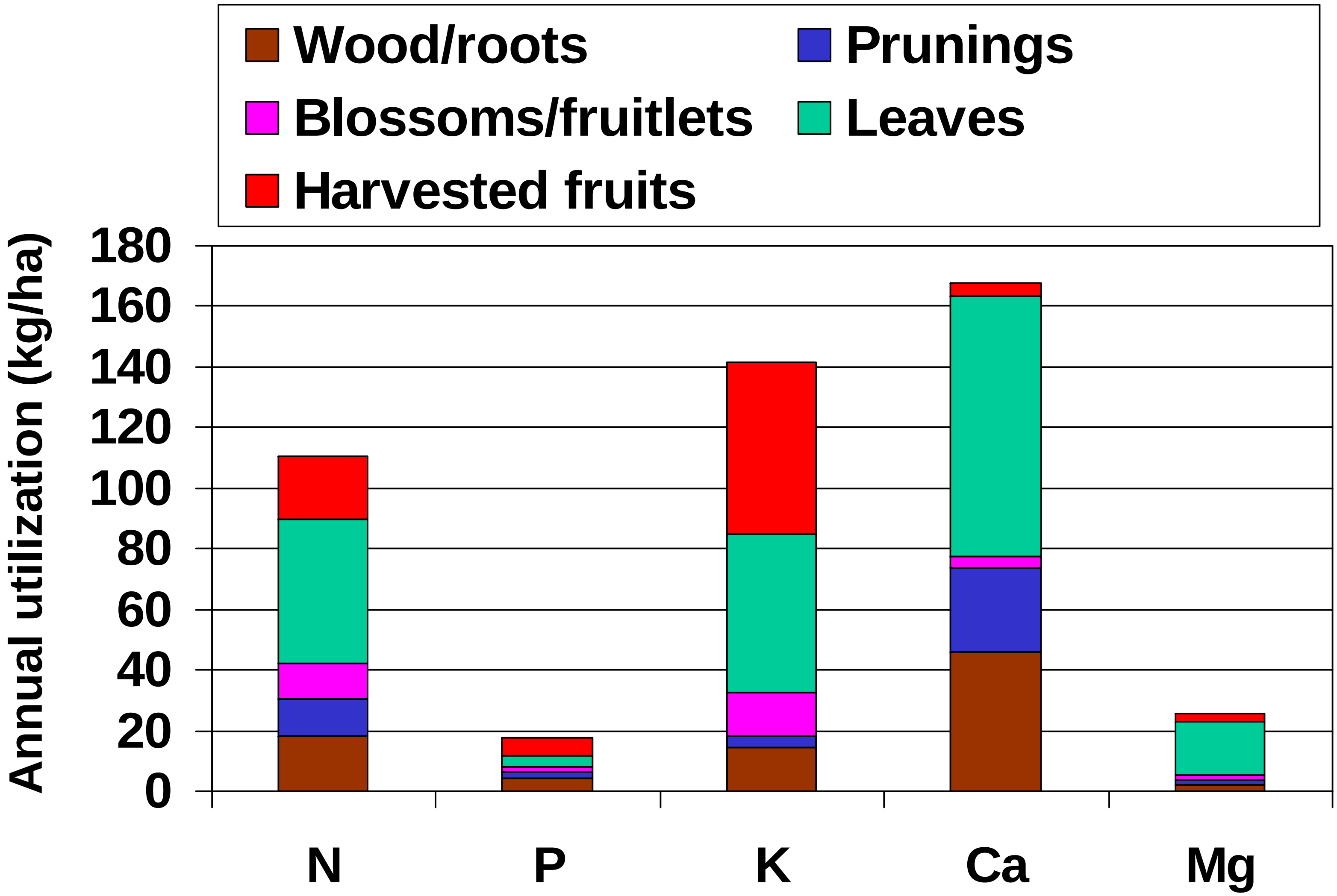
- **Nutrients are removed from the orchard in fruit at harvest**
- **Nutrients are retained as reserves in dormant tissues (buds, bark & roots) for re-mobilization in the spring**
- **Nutrients are re-cycled back into the soil as thinned flowers & fruits, leaves & prunings**

Peak Nutrient Demand

- Bloom
- Fruit set
- Flower bud formation
- Fruit maturation

Nutrient Utilization

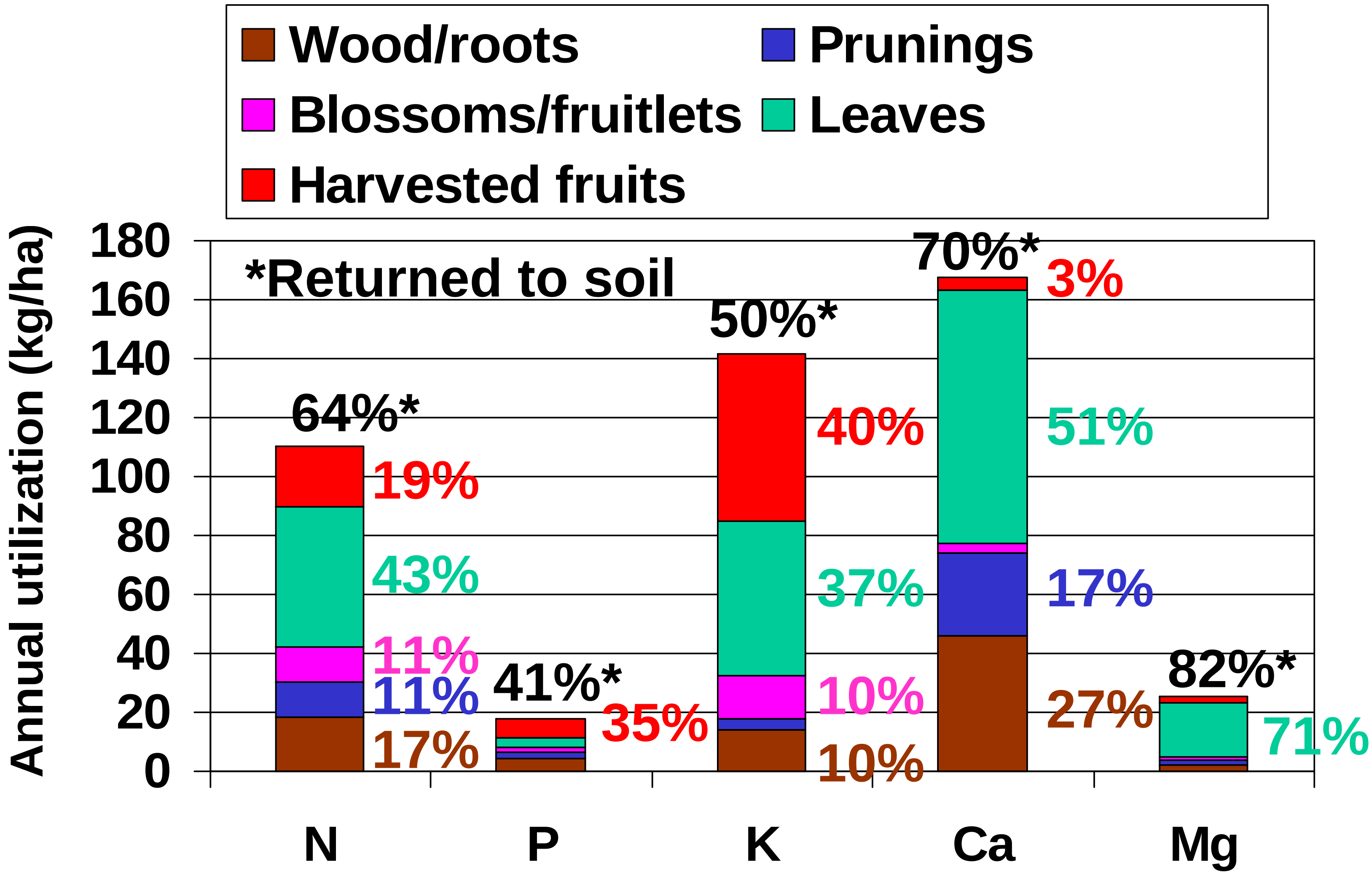
Mature 'Delicious' orchard



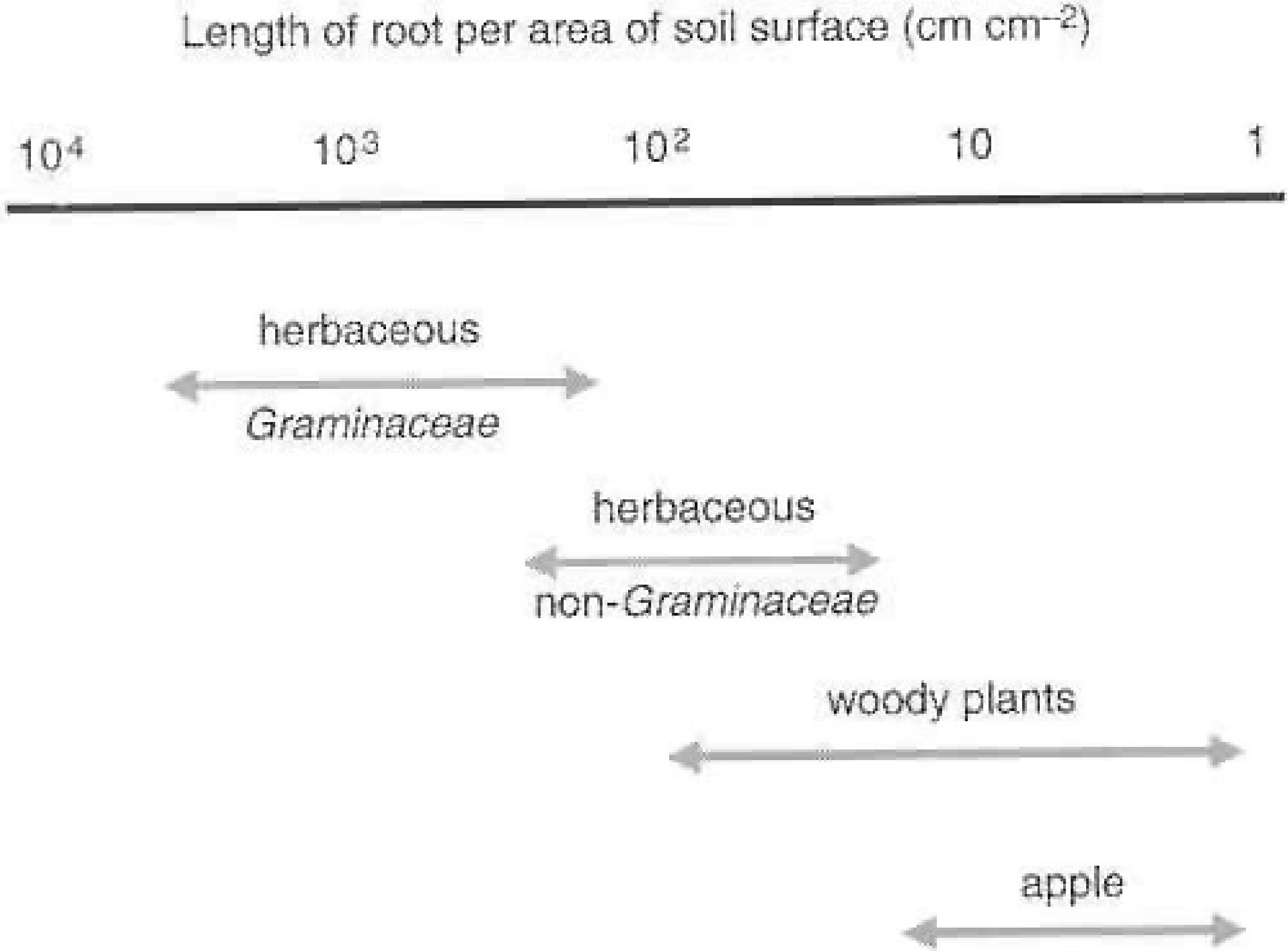
Batjer et al, 1952

Nutrient Utilization

Mature ‘Delicious’ orchard

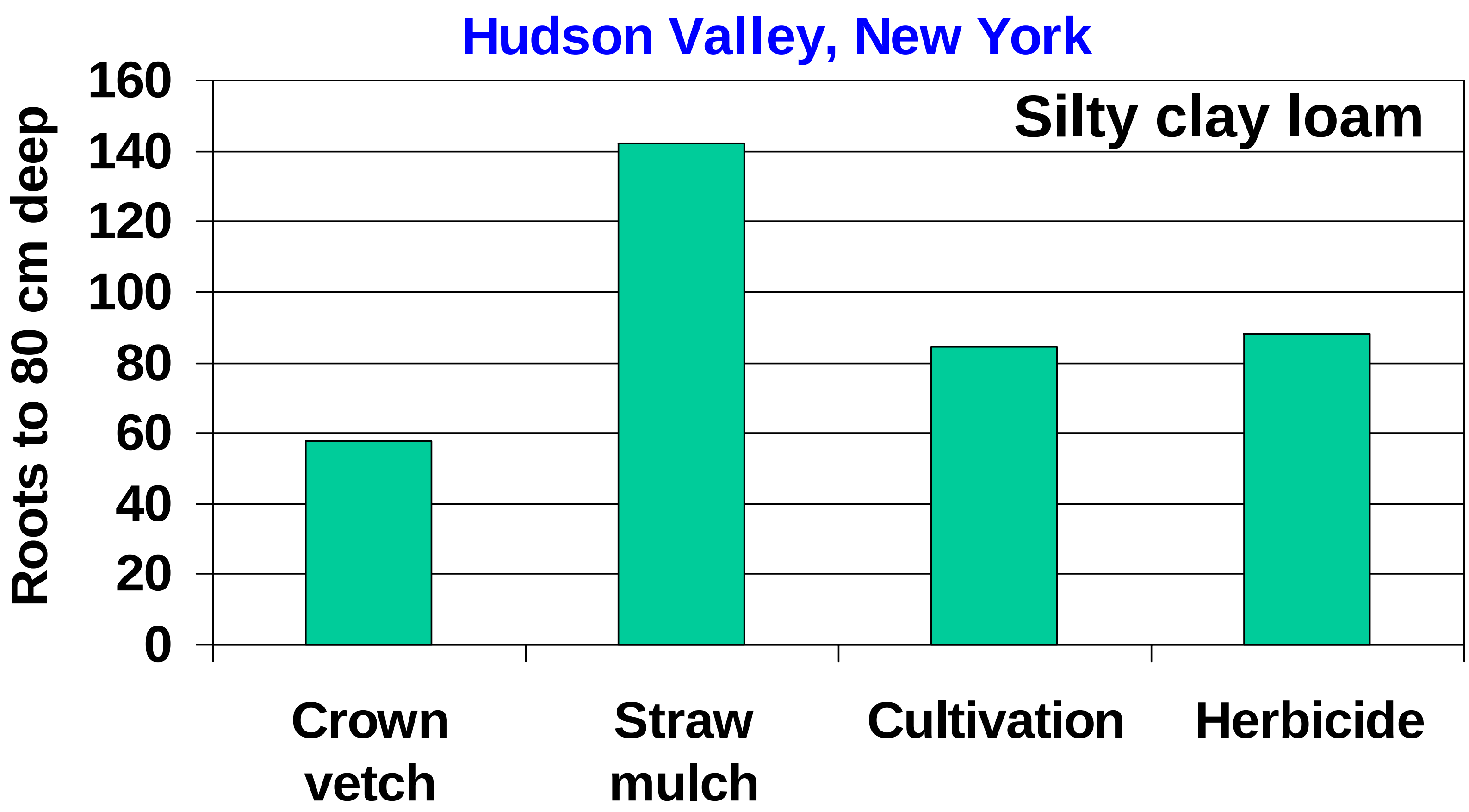


Root Densities



Roots

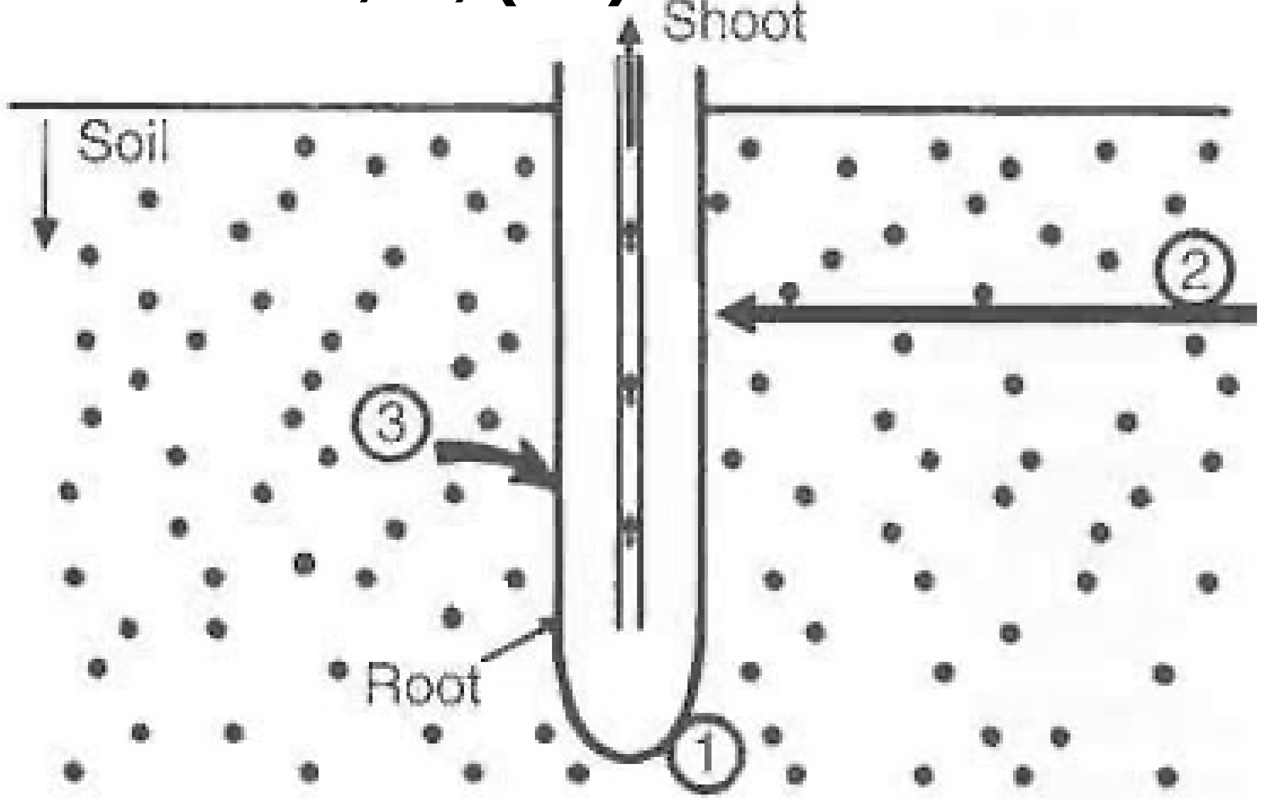
‘Jonagold’/MM111 apple



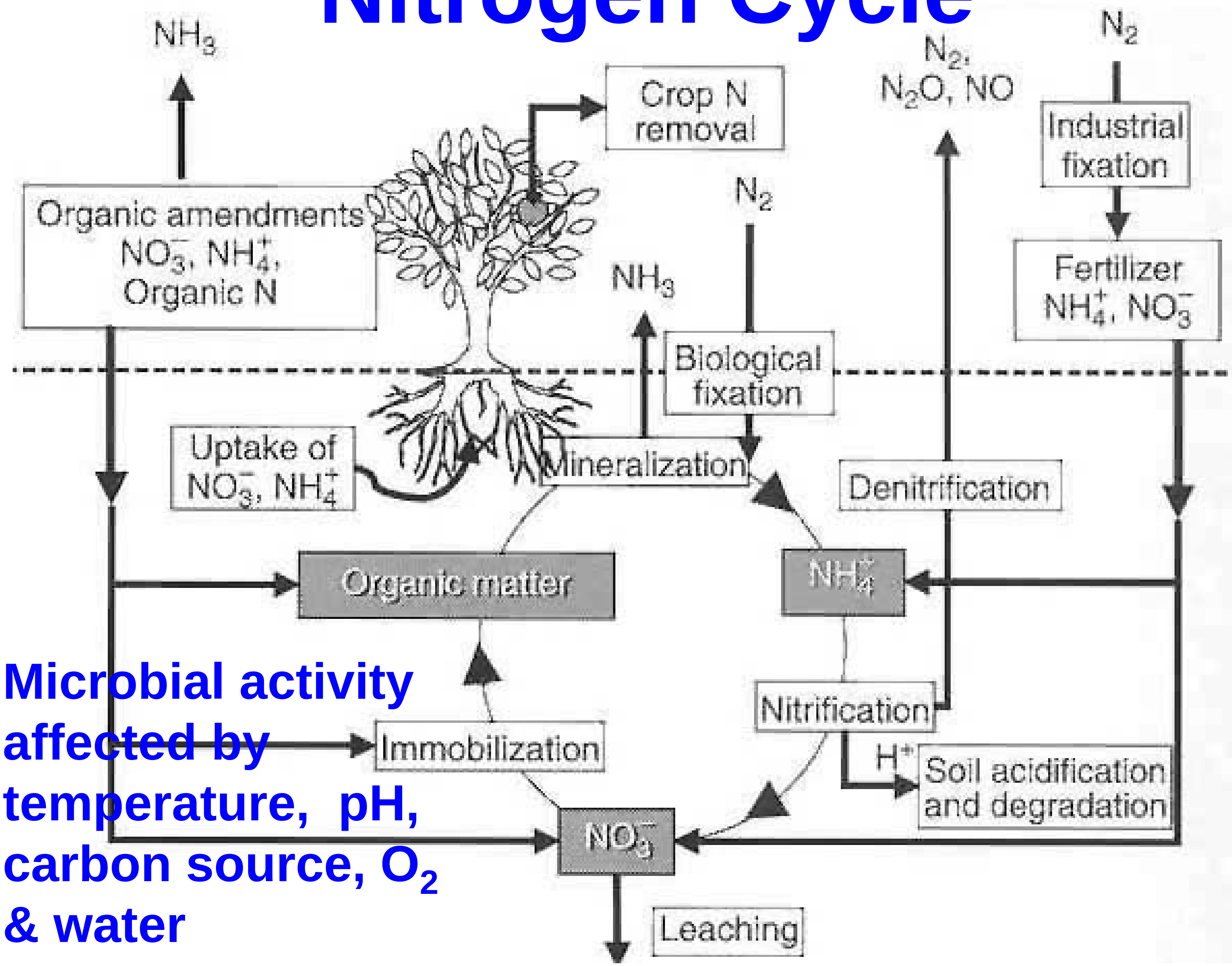
Merwin et al., 1994

Nutrient Pathways to Roots

1. Root interception: Ca, (Zn)
2. Mass flow of water: N, Ca, Mg, S, B, (K), (Zn)
3. Diffusion: P, K, (Zn)

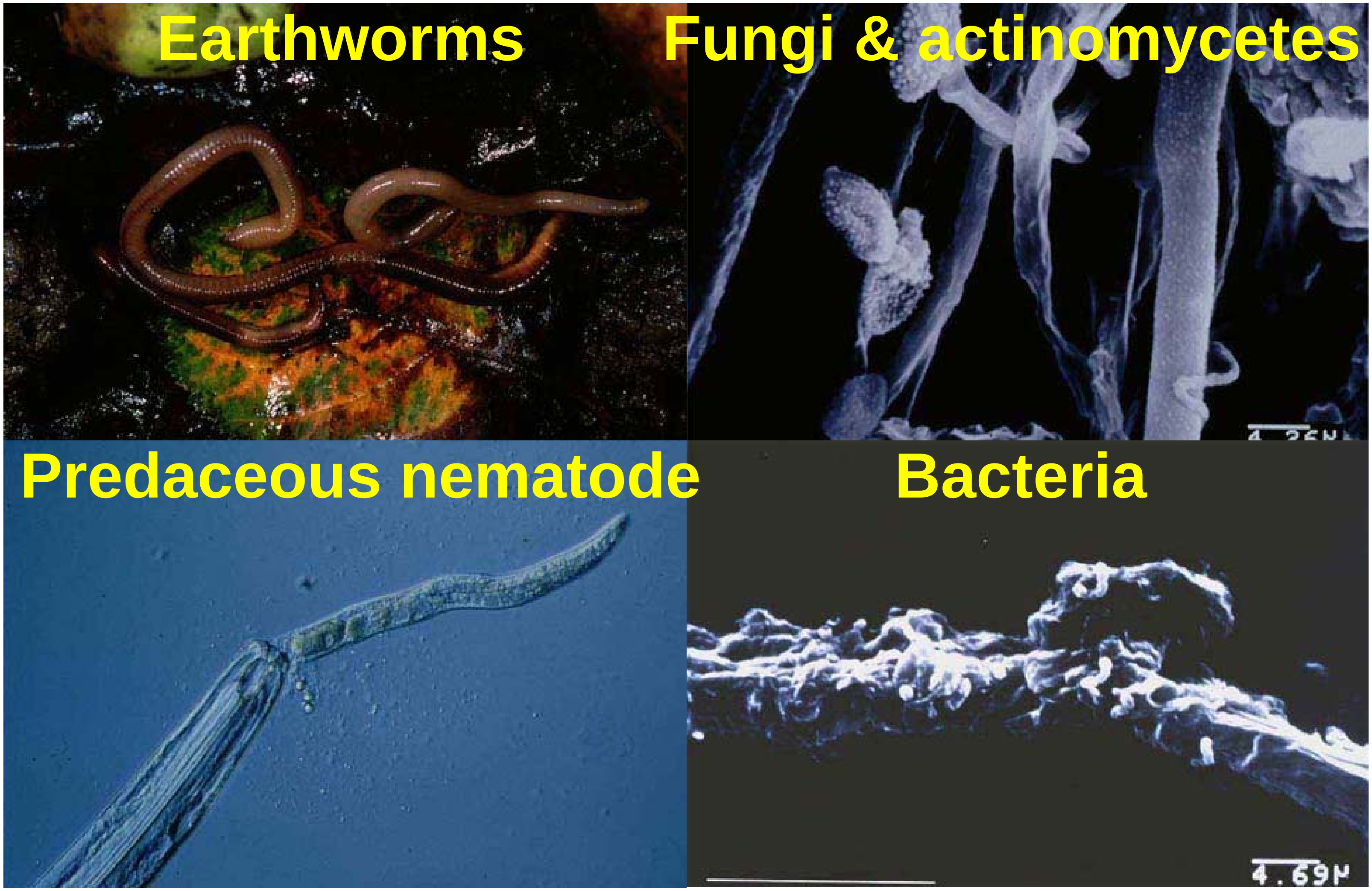


Nitrogen Cycle



Microbial activity affected by temperature, pH, carbon source, O_2 & water

Soil Organisms



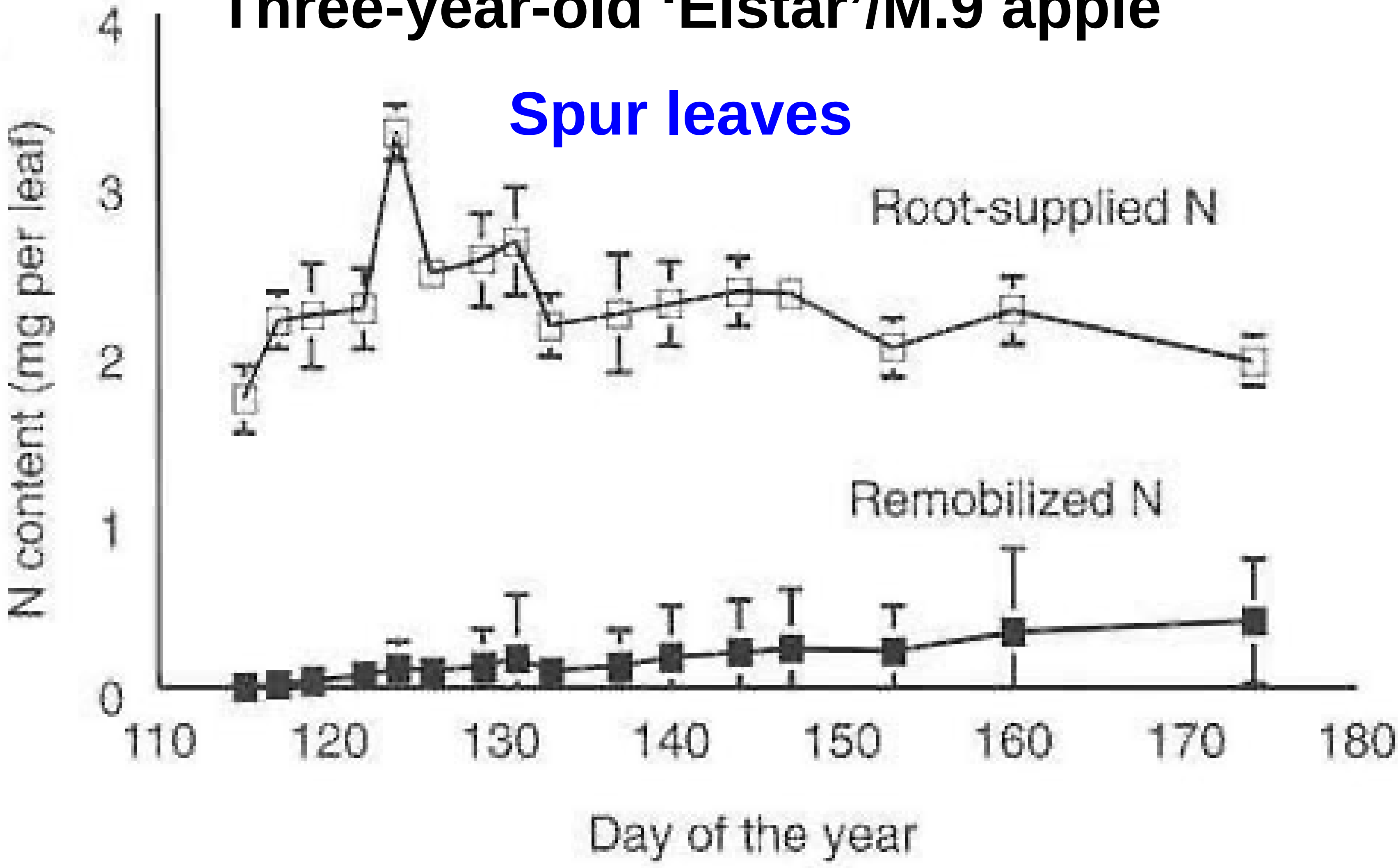
Nitrogen Uptake & Utilization

- NO_3^- or NH_4^+ ions absorbed by roots
- NO_3^- reduced to NH_4^+ by nitrate reductase
- NH_4^+ assimilated into amino acid glutamine
- Glutamine converted to amino acids glutamate & aspartate
- 90% of N transported in xylem are amino acids

- **Leaves are major sinks for amino acids, which are converted into proteins (esp. ribulose-1,5-bisphosphate carboxylase-oxygenase)**
- **During leaf senescence, N is transported & stored as proteins in buds, bark, wood & roots**
- **In spring, soluble N re-mobilized from bark, wood & roots for new growth**

Nitrogen Supply

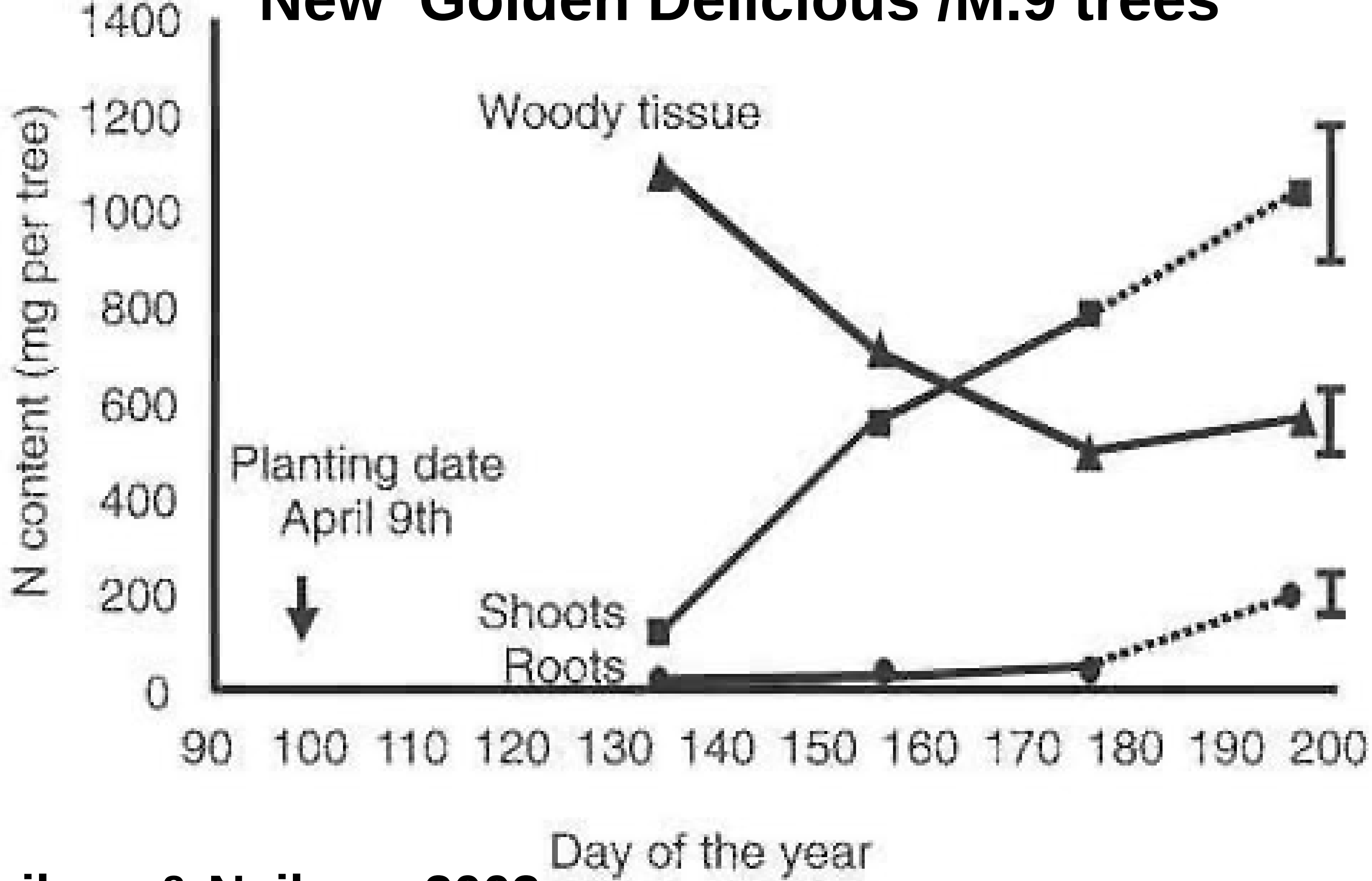
Three-year-old ‘Elstar’/M.9 apple



Neilsen & Neilsen, 2003

Re-Mobilized Nitrogen

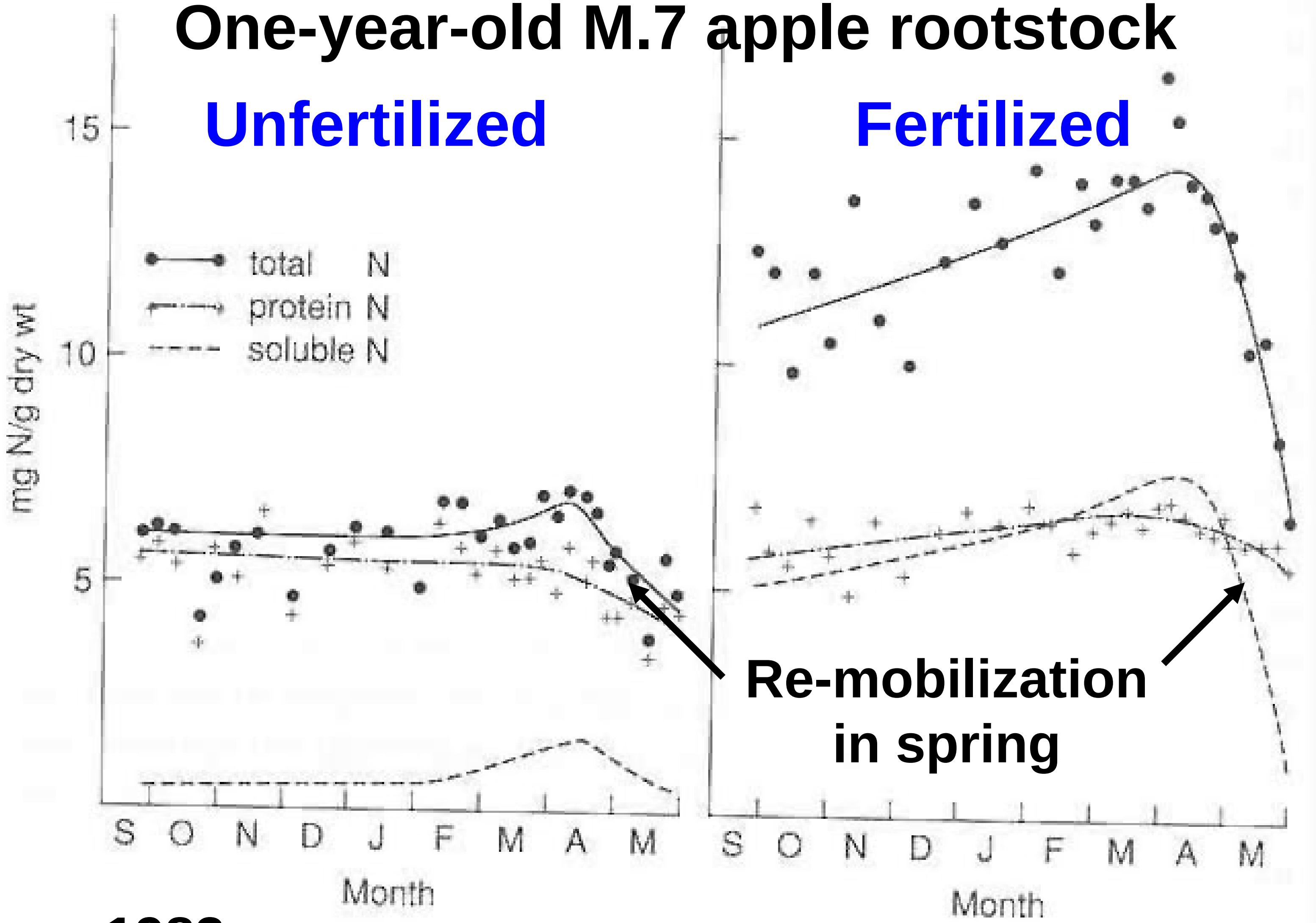
New 'Golden Delicious'/M.9 trees



Neilsen & Neilsen, 2003

Protein & Soluble Nitrogen

One-year-old M.7 apple rootstock



Tromp, 1983

Nitrogen Fixation

Root nodules fix N

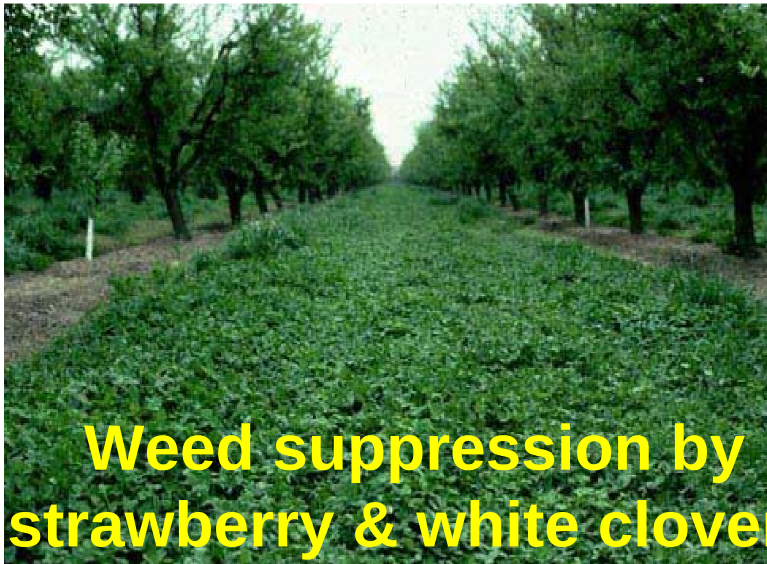
Rye grass & red clover
15-105 kg N/ha/year
(New Zealand)

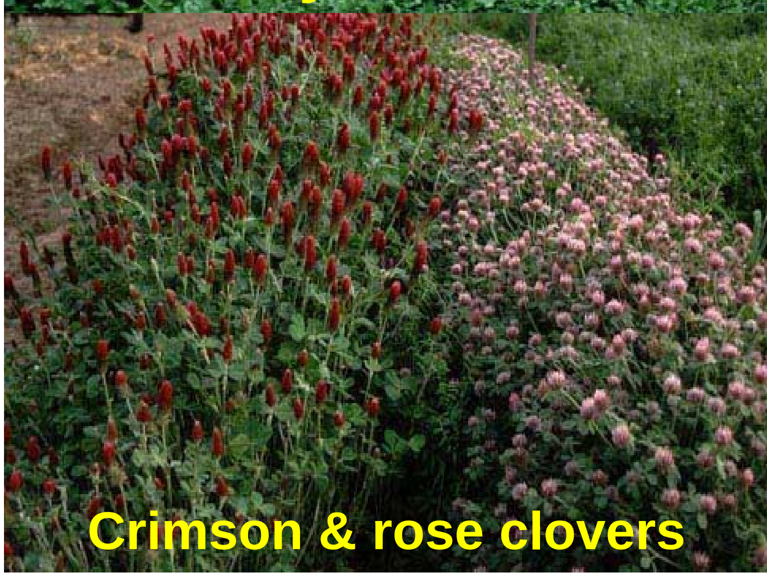
Better nutrient cycling

Cover Crops

- **Nutrient availability**
- **Weed control**
- **Water infiltration & soil moisture retention**
- **Improve soil quality**

Legume Cover Crops





Cover Crops for Nutrients

- Winter rye, hairy vetch & white clover (hot, arid, temperate climate)
- Management:
  - Mown (left in place or mulch in tree row)
  - Tilled in green manure crop
  - Undisturbed
  - Combination

Cover Crop Information

UC SAREP Cover Crop Resources

http://www.sarep.ucdavis.edu/ccrop/index.htm

Cover crop list & database
Slide show for orchard cover crops
Papers & books
Internet links

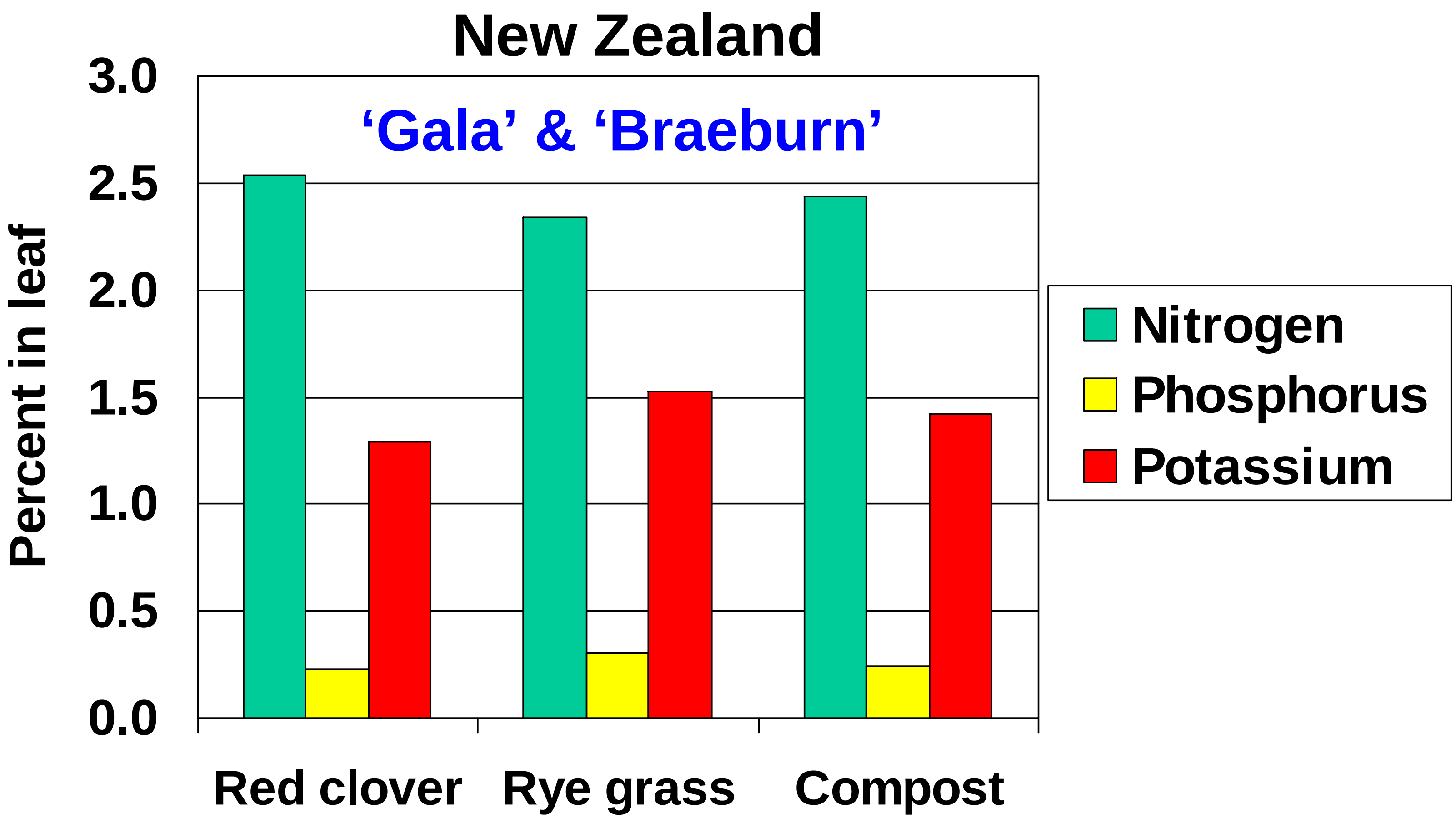
Soil Physical Properties

Hudson Valley, New York (clay loam soil)

Soil property	Mulch	Herbicide
Bulk density (g/cm^3)	1.21	1.42
Porosity	0.58	0.52
Infiltration rate (mm/sec)	1.24	0.87

Oliveira & Merwin, 2001

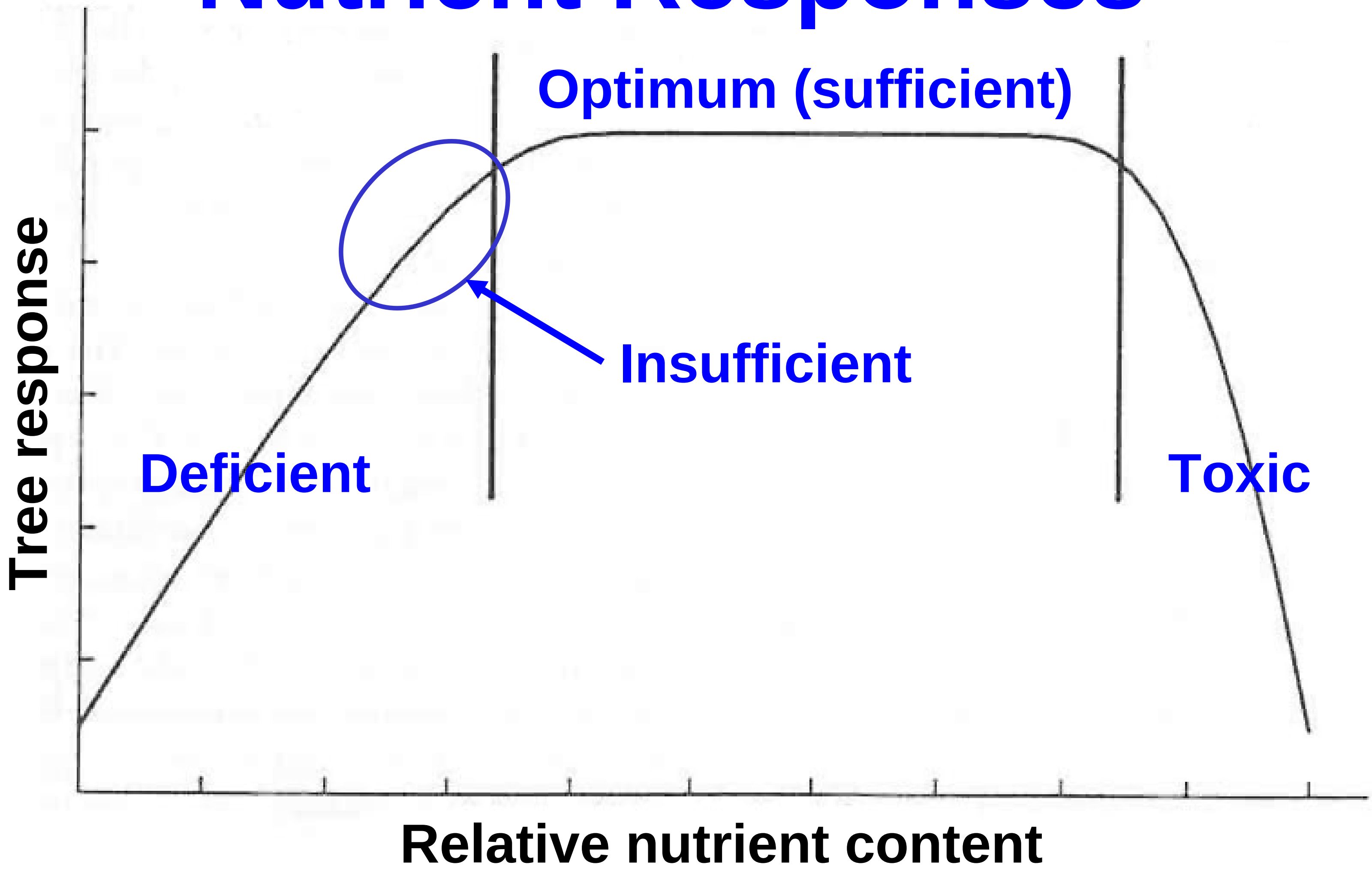
Leaf Nutrients



Leaf Nutrient Status

- **Deficient:** visual symptoms
- **Insufficient:** no visual symptoms, but applications improve productivity and/or fruit quality
- **Optimum (Sufficient):** range of nutrient concentrations that result in optimum productivity & fruit quality
- **Toxic:** excess nutrient(s), with or without symptoms

Nutrient Responses



Leaf Nutrient Concentrations

Apple

Nutrient	Sufficient range
N (%)	1.7 – 2.5
P (%)	0.15 – 0.30
K (%)	1.5 – 2.5
Ca (%)	1.2 – 2.0
Mg (%)	0.26 – 0.36
Fe (ppm)	45 – 500 (?)
B (ppm)	20 – 60
Zn (ppm)	15 – 120

Determining Nutritional Status

- **Soil analysis:** At planting, then every 3-5 years, or more frequently in suspected problem areas
- **Tissue analysis:** Every year; integrates soil nutrient availability, uptake & utilization by tree; reported as concentration (%DW or ppm)

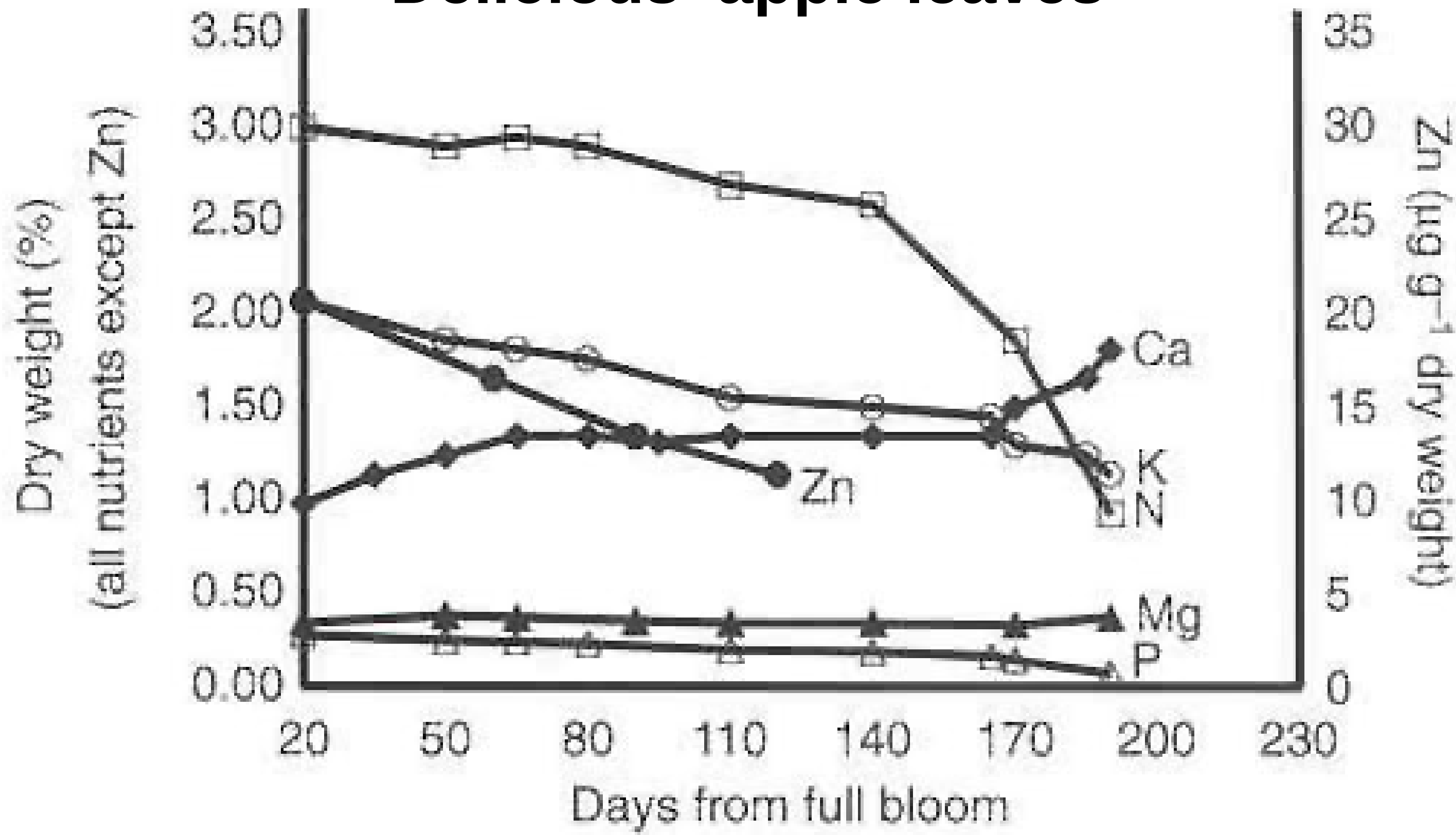
  Leaves sampled late July to early Aug

  Fruit sampled a few weeks before harvest

Mid-Shoot Leaf Samples

Seasonal Nutrient Levels

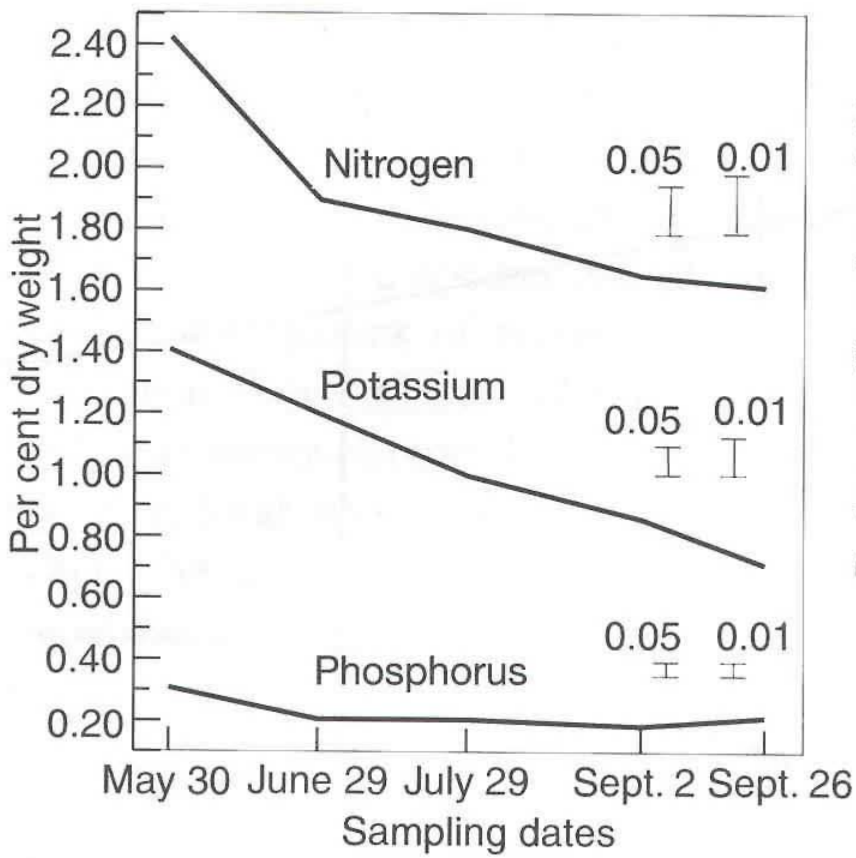
'Delicious' apple leaves

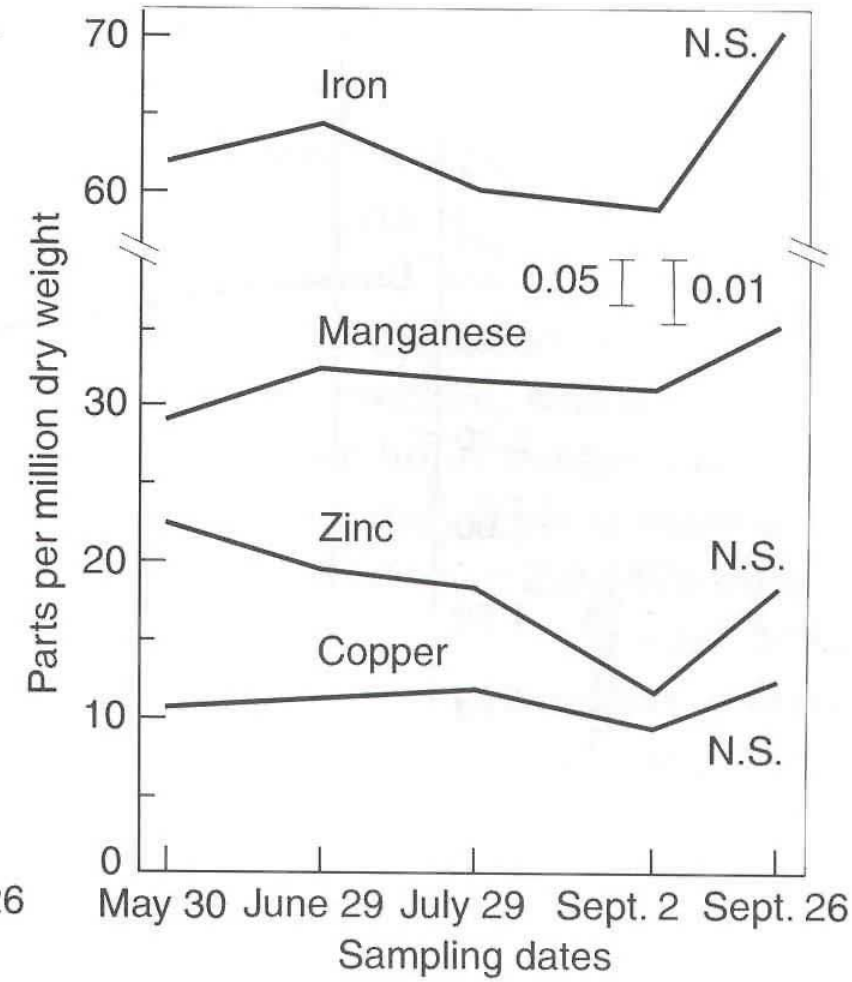


Rogers et al, 1953

Seasonal Nutrients

'Bing' sweet cherry leaves





Christensen & Walker, 1964

Factors in Nutrient Variability

- **Geographic area:** warmer growing regions require ↑N than cooler regions
- **Fruit:**

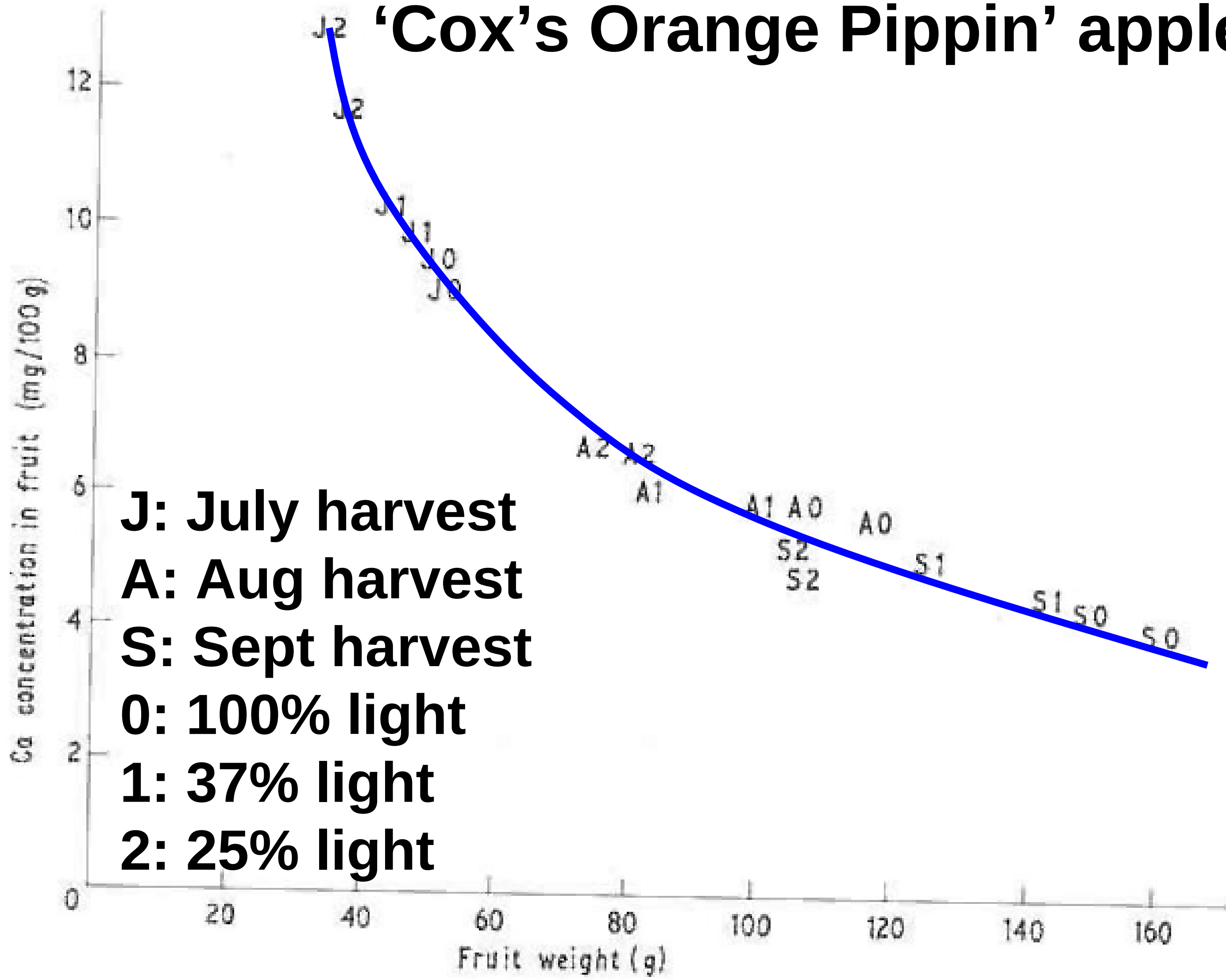
  ↑ [K], [Ca], [Mg] in skin & core, ↓ in flesh

  ↑ [P], [Fe], [Zn], [B] in skin, ↓ toward core

  Calyx end ↓ concentrations than stem end
- **Crop load & fruit size**
- **Soil management practices:** weed and/or cover crop competition, soil fertility
- **Irrigation practices**

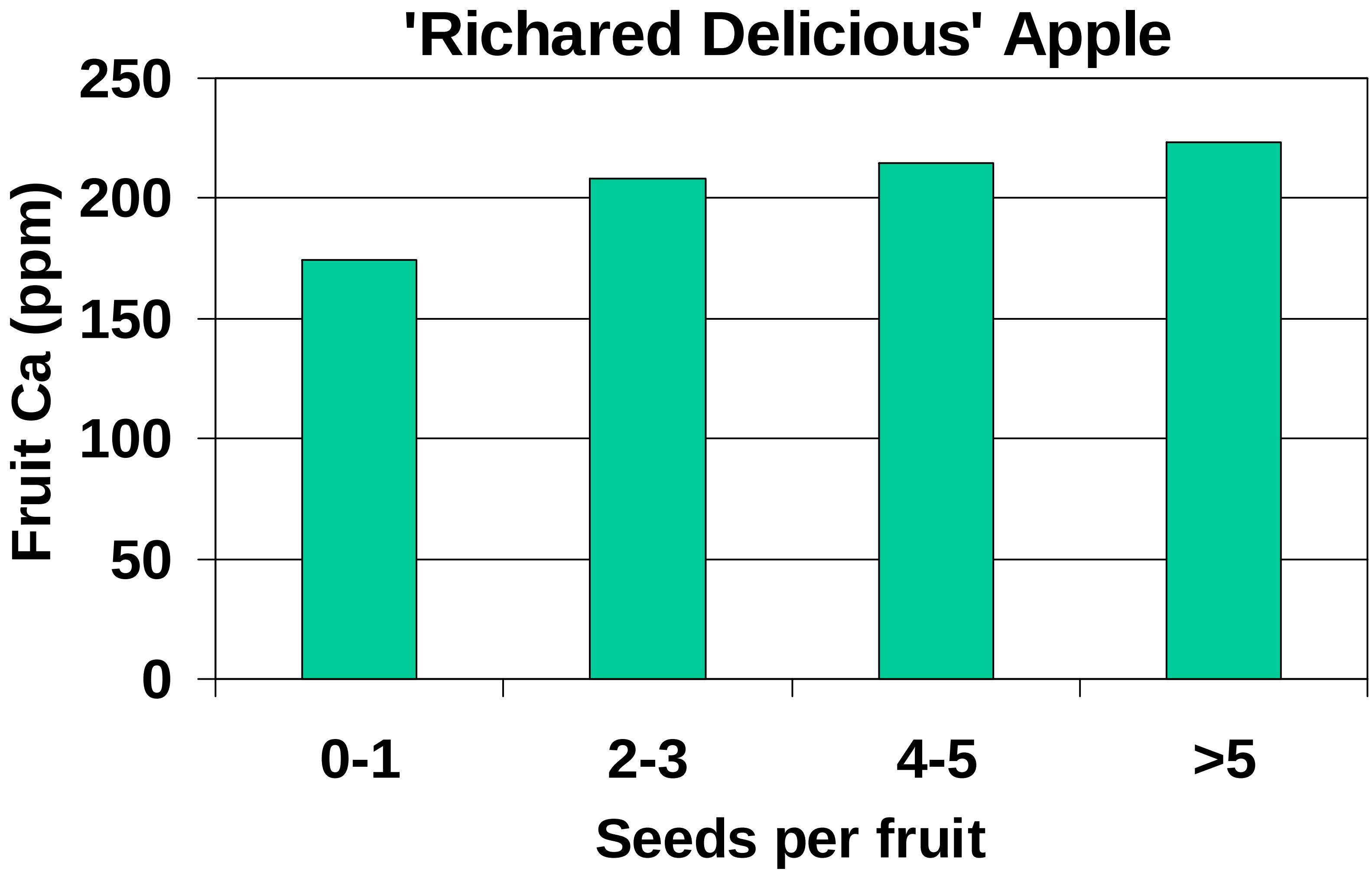
Fruit Size & Calcium

'Cox's Orange Pippin' apple



Jackson et al, 1977

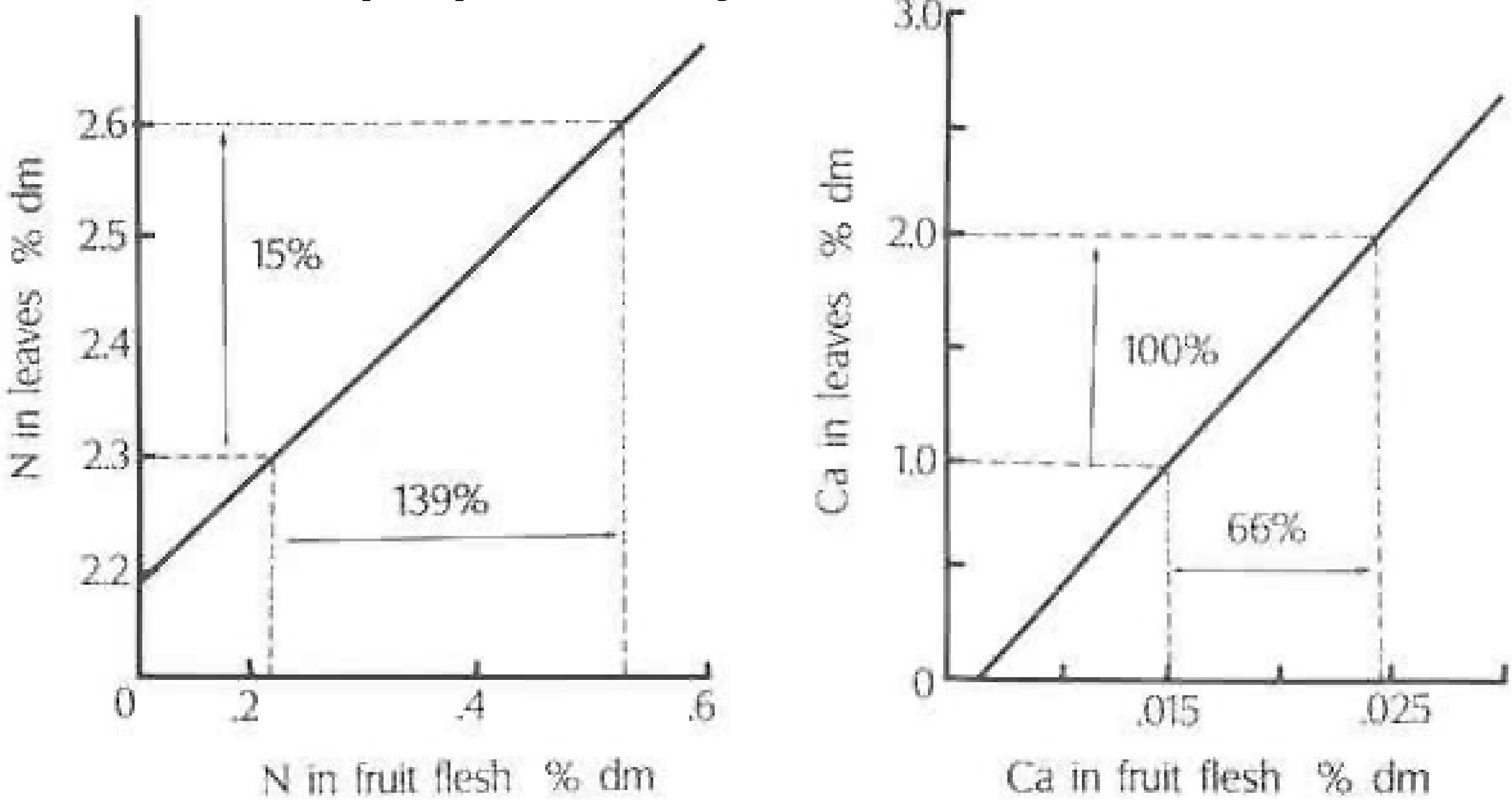
Seeds & Calcium



Bramlage et al, 1990

Nitrogen & Calcium

Compared with Ca, N fertilizing increases N content in the fruit proportionally more than in the leaves



Shear, 1974

Nutrient Ratios

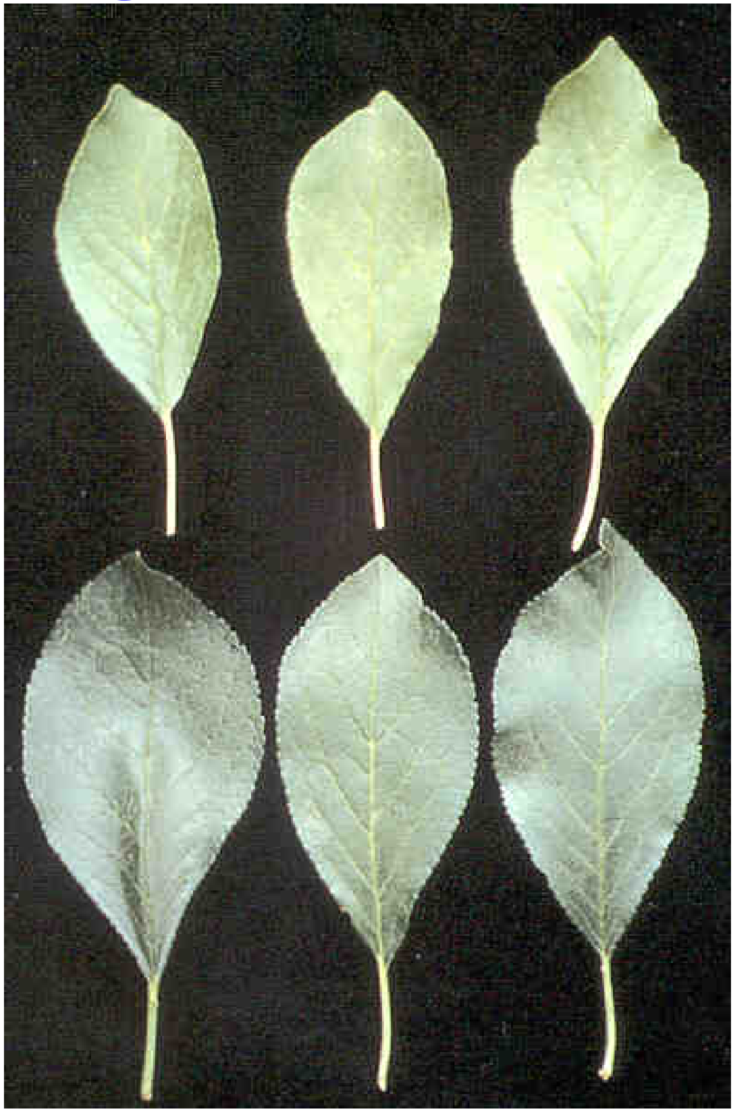
- **N:Ca – Low ratios usually result in fruit with better storage potential**
- **Mg:Ca or Mg+K:Ca – High ratios usually result in insufficient Ca for good storage potential because Mg & K are antagonists to Ca accumulation in fruit**

Nutrient Requirements

- **Nitrogen: major component of nucleic acids, proteins & secondary metabolites**

  Applications usually needed every year
  - **↑ vegetative growth, flowering, fruit set, fruit growth**
  - **↓ fruit color, accentuates Ca-related disorders**

Nitrogen Deficiency



Prune

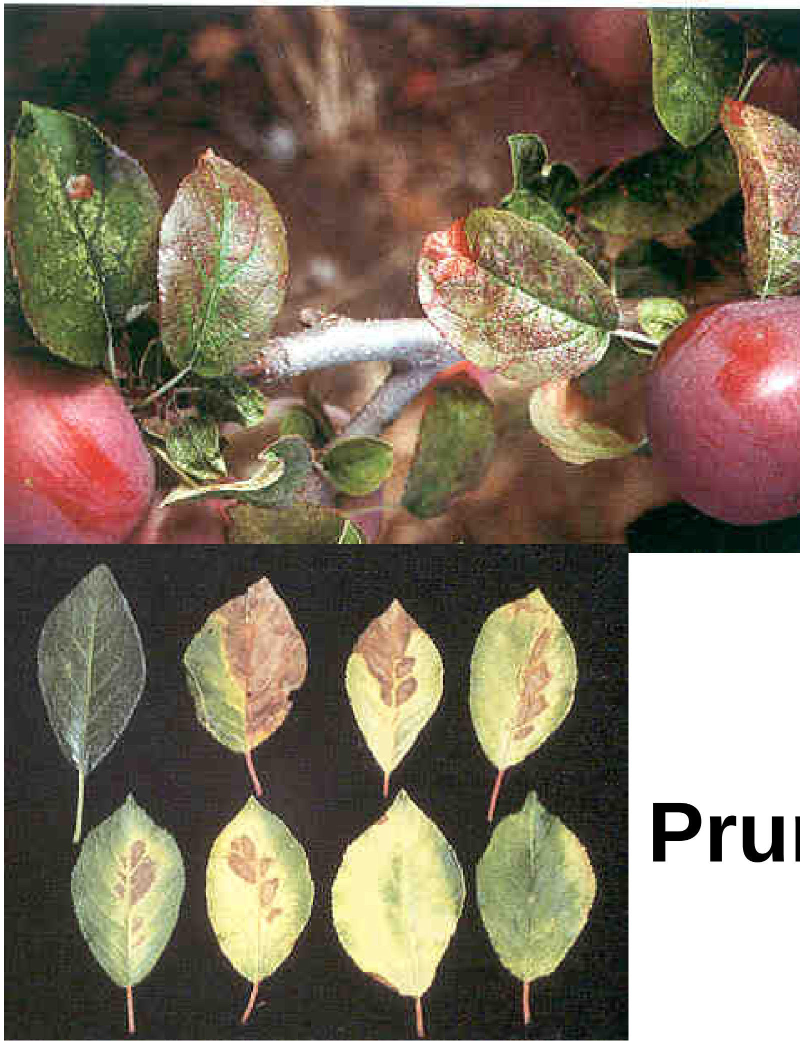
Deficient

Sufficient

- **Phosphorus:** **constituent of DNA & RNA, energy transfer via ATP**
  - **Usually applied to young trees to improve root growth (mono-ammonium phosphate, 11-55-0)**
- **Potassium:** **enzyme regulation, protein synthesis, trans-membrane pH gradient in Ps, osmo-regulation, stomatal conductance**
  - **Very abundant in soil & very mobile in phloem**
  - **Application not usually needed, may improve fruit color**

Potassium Deficiency

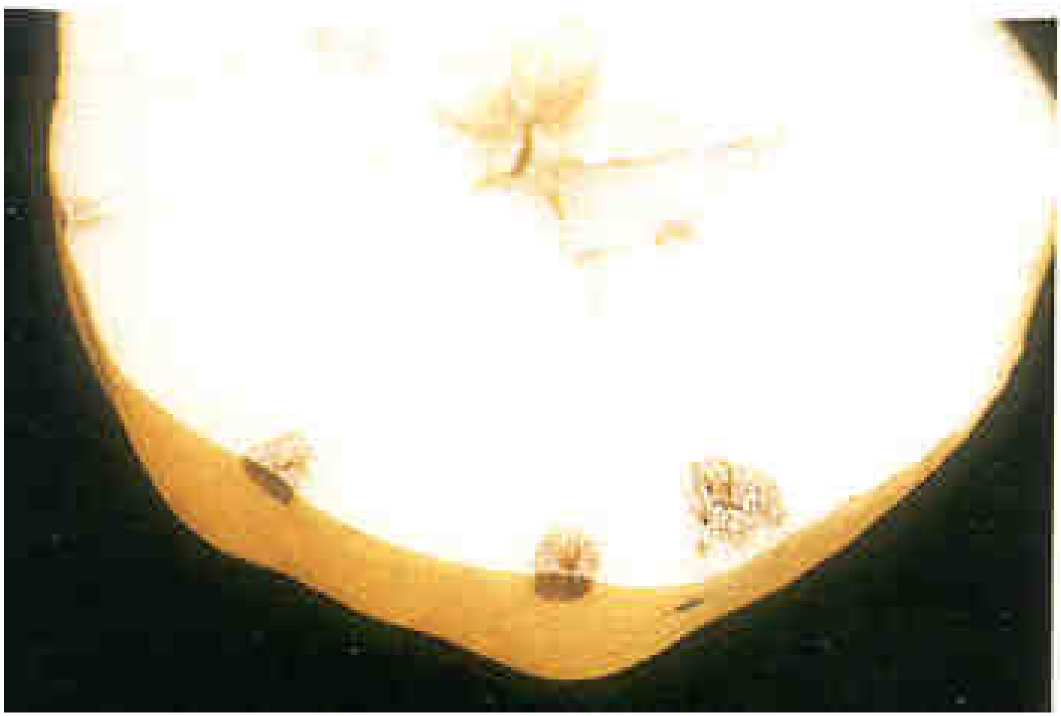
Apple



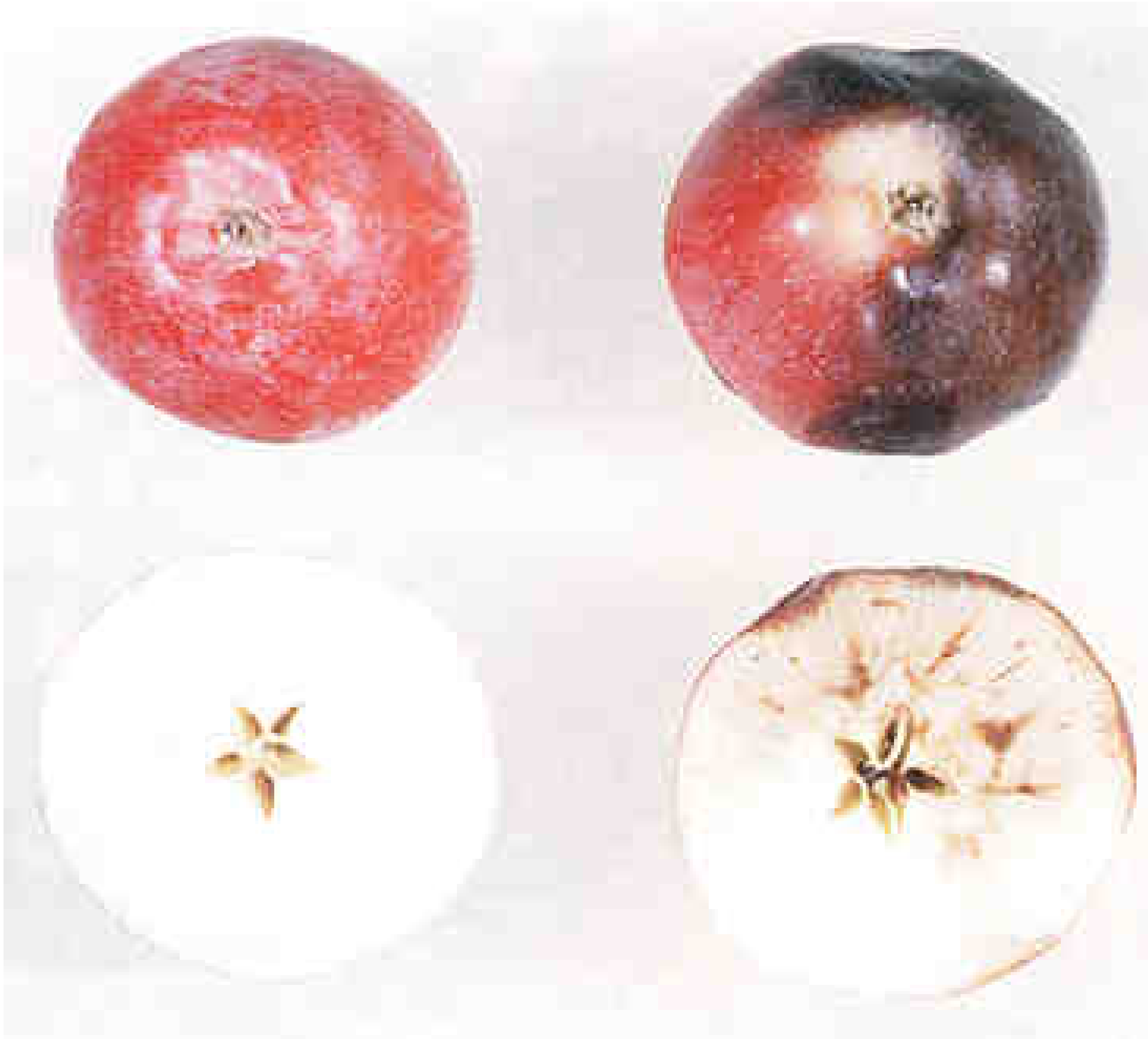
Prune

- **Calcium:** **constituent of cell walls & regulatory signal for metabolism; critical for fruit quality & storability**
  - **Ca-related disorders: bitter pit, watercore, cork spot, lenticel spot**
  - **Root-derived Ca accumulates during first 4-6 weeks after bloom**
  - **Ca diluted as fruit grow**
  - **High N and/or Mg reduces fruit Ca**
  - **Must apply as foliar sprays**

Bitter Pit of Apple



Internal Breakdown of Apple



- **Zinc:** **enzyme co-factor, cell pH regulation**
  - **Very low concentration in soil**
  - **Poor shoot & leaf growth; rosette leaf pattern under severe deficiency**
- **Boron:** **maintains meristematic activity & cell wall stability**
  - **Commonly deficient in PNW soils**
  - **Poor fruit set & cork tissue forms in flesh of fruit under severe deficiency**

Zinc Deficiency

Apple

Peach

Prune

Boron Deficiency of Apple

Boron Toxicity of Apple

- **Iron:** **constituent of complex for electron transport**
  - **Lime-induced chlorosis in calcareous ($CaCO_3$) soils with high pH; aggravated by excess irrigation, especially in shallow soils**

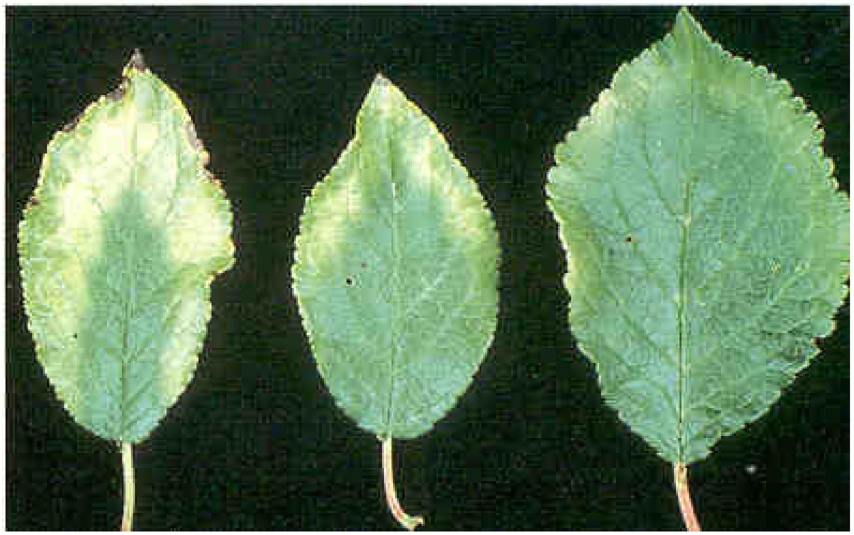
Iron Deficiency

Apple

Prune

Magnesium Deficiency

Apple



Prune

Ground Applications

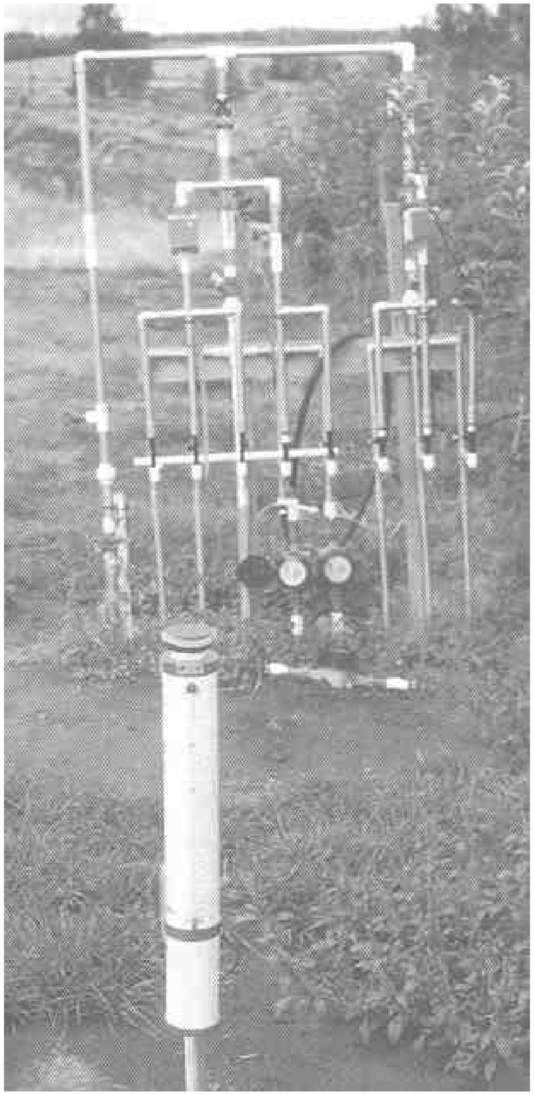
- **Requires root activity (usually spring & autumn) for nutrient uptake**
- **Usually N, P, K**
- **Single vs. split applications:**

  Single spring application: nutrients not available for budbreak, bloom or fruit set, which must come from reserves, but will supply N for shoot & fruit growth

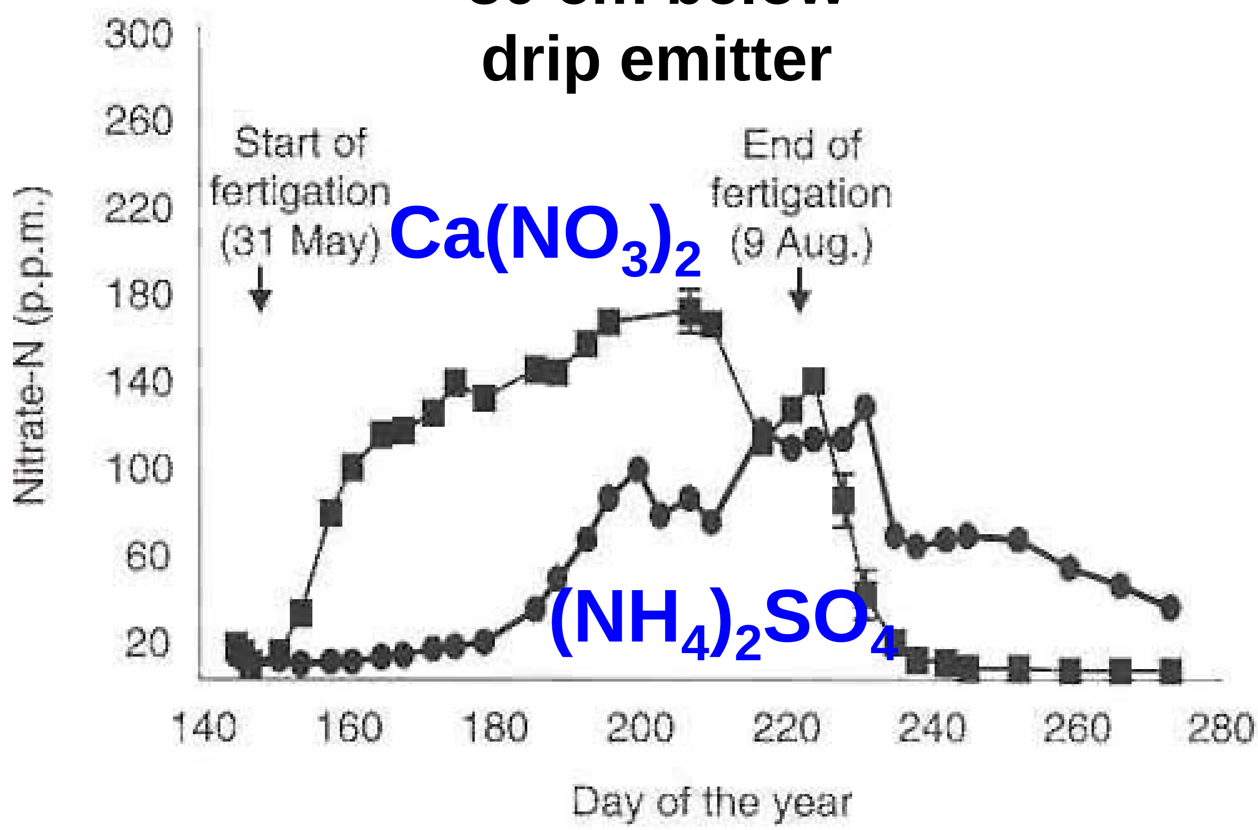
  Split spring + autumn applications: ↑N reserves in roots, which supplies more N for budbreak, bloom & fruit set

- **Mature trees on more vigorous rootstocks in fertile soil are less sensitive to N applications because of large stored N reserves**

Fertigation System



Soil nitrate
30 cm below
drip emitter



Neilsen & Neilsen, 2003

Foliar Applications

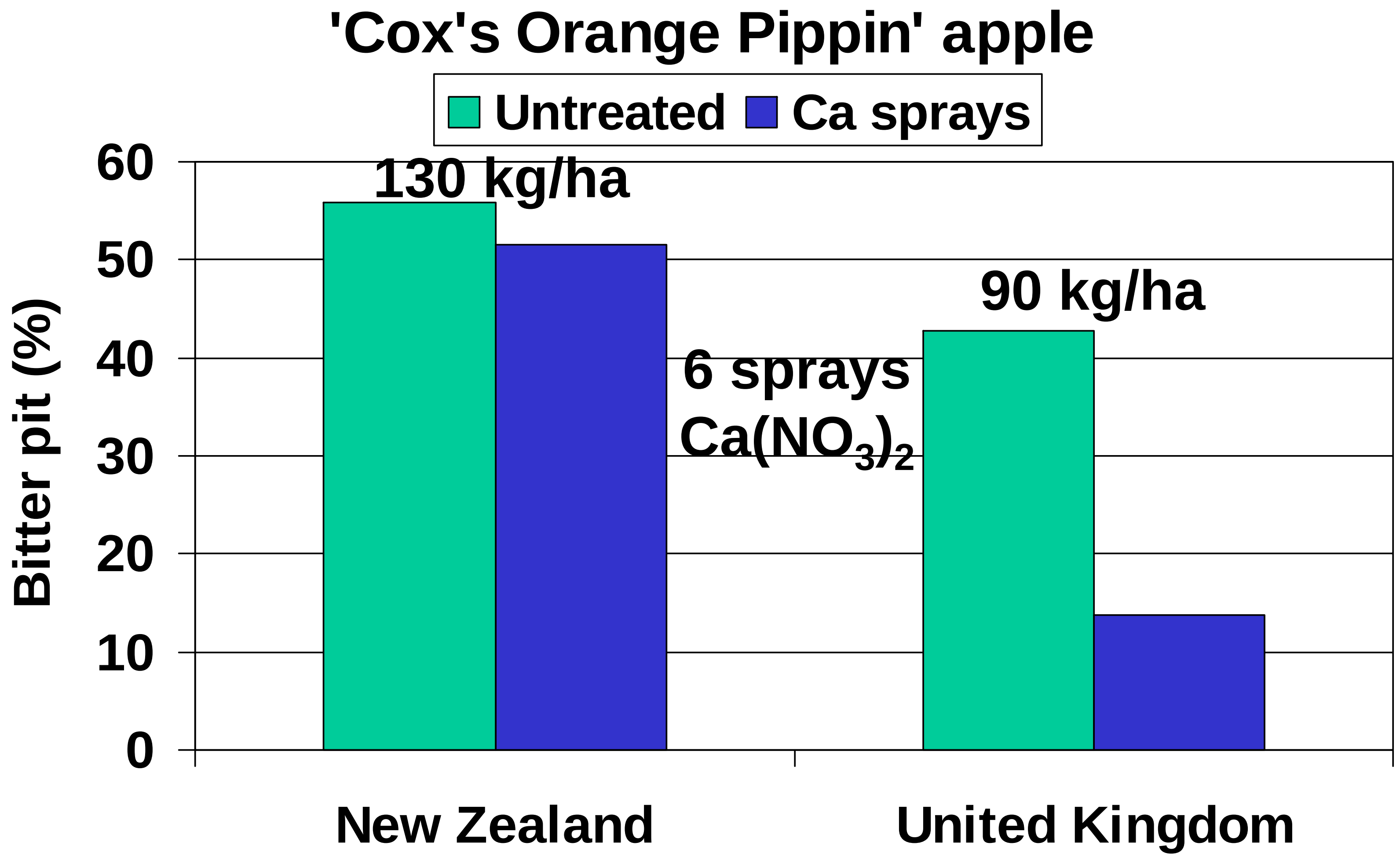
- Healthy leaves absorb more nutrients
- Urea: Post-harvest applications increase N reserves in bark, which are more available for budbreak, bloom & fruit set
- Nutrients immobile in soil (Fe & Zn) or plant (Ca & B)

  Zinc: dormant or delayed dormant

  Boron: pre-pink or pink stage

  Calcium & Iron: post-bloom to harvest

Calcium & Bitter Pit



Sharples, 1980

Approved Organic Materials

http://www.ams.usda.gov/nop/NationalList/ListHome.html

http://www.omri.org/

Organic Fertilizer Materials

- Elemental sulfur
- Gypsum & dolomitic lime
- Sodium nitrate (Chilean) – limited use
- Rock phosphate
- Potassium & magnesium sulfate
- Calcium chloride
- Micronutrients:
  - Soluble boron
  - Zinc, copper, iron & manganese sulfates, carbonates, oxides & silicates

Organic Fertilizer Materials

- Aquatic plant extracts (seaweed or kelp)
- Liquid fish products
- Blood, bone, egg shell & feather meal
- Humic acids
- Bird & bat guano
- Plant extracts
- Manure, processed (with restrictions)
- Compost (properly processed)

Organic Amendments

Carbon:Nitrogen Ratio

• **Low** legume	**15:1–20:1**	**Releases N rapidly** (Excess N?)
• **Medium** mustard	**20:1–30:1**	**Intermediate**
• **High** grass	**40:1–80:1**	**Releases N slowly** (Ties up N?)

Sustainability of Three Apple Production Systems: Organic, Conventional & Integrated

John Reganold
Jerry Glover
Preston Andrews
Herb Hinman

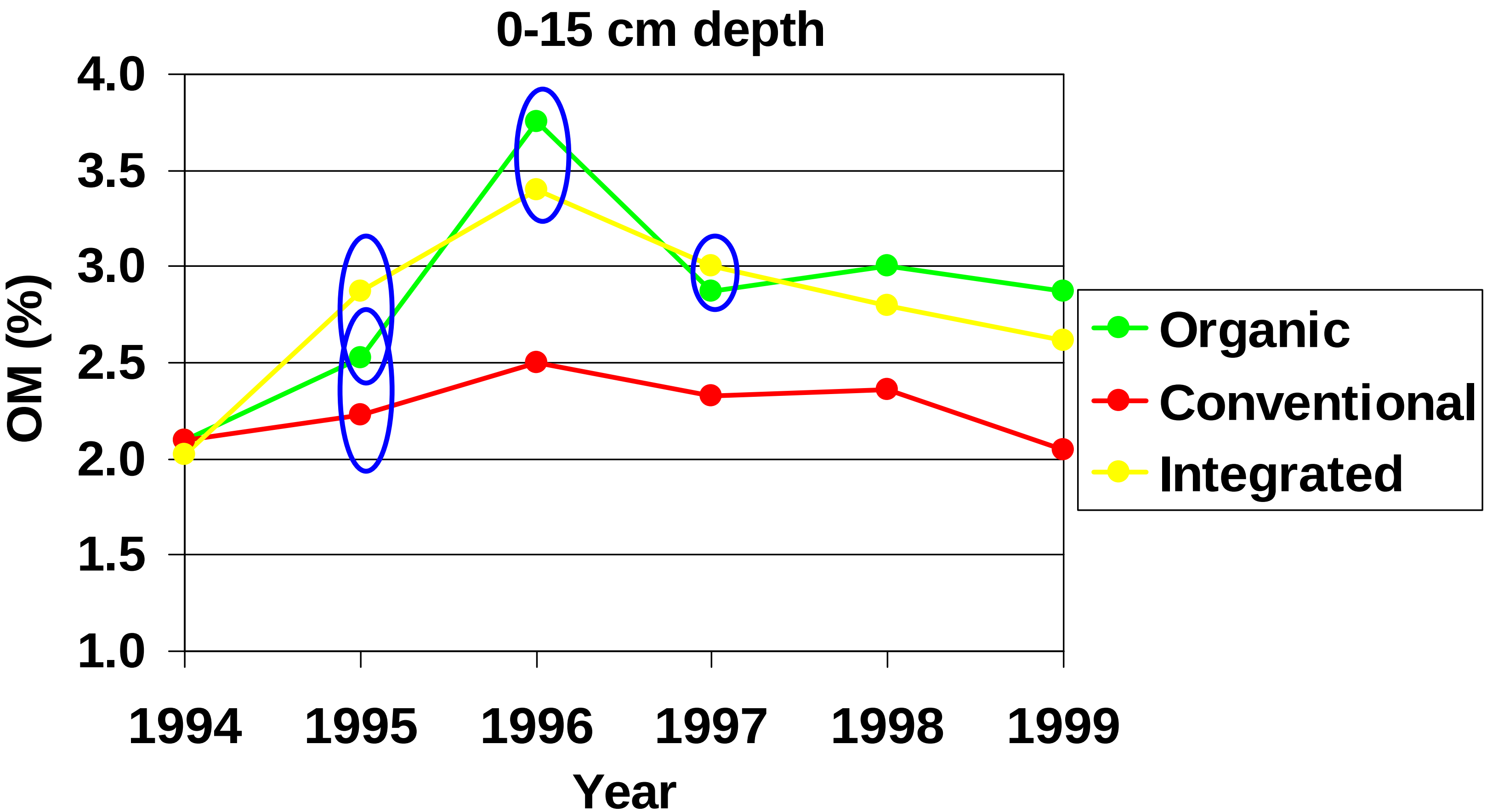
***Nature* 410: 926, 2001**


BRITISH COLUMBIA
CANADA
IDAHO
OREGON
125°
124°
123°
122°
121°
120°
119°
118°
117°
49°
48°
47°
46°
Ferndale
Lynden
Bellingham
Friday Harbor
Anacortes
Victoria
Sedro-Woolley
Mount Vernon
Oak Harbor
Coupeville
Port Angeles
Sequim
Port Townsend
La Push
Forks
Everett
Edmonds
Quilcene
Seattle
Bellevue
Bremerton
Snoqualmie
Port Orchard
Renton
Kent
Federal Way
Pacific Beach
Tacoma
Shelton
Olympia
Puyallup
Hoquiam
Montesano
Aberdeen
Tumwater
Lacey
Centralia
Chehalis
South Bend
Long Beach
Cathlamet
Longview
Kelso
Woodland
Vancouver
Camas
Washougal
Stevenson
White Salmon
Goldendale
Okanogan
Omak
Republic
Colville
Chewelah
Newport
Brewster
Coulee Dam
Grand Coulee
Chelan
Waterville
Leavenworth
Wenatchee
Davenport
Spokane
Opportunity
Medical Lake
Cheney
Ephrata
Quincy
Ritzville
Moses Lake
Ellensburg
Colfax
Pullman
Selah
Yakima
Pomeroy
Clarkston
Sunnyside
Toppenish
Grandview
Prosser
Richland
Pasco
Kennewick
Dayton
Asotin
Walla Walla
Kirkland
Port Orchard
Seattle
0 5 10 mi
0 6 12 km
0 15 30 45 60 mi
0 20 40 60 80 km
WASHINGTON
CITIES
State and provincial capitals
County seats
Cities
BOUNDARIES
International
State
County
©1998, Encyclopædia Britannica, Inc.

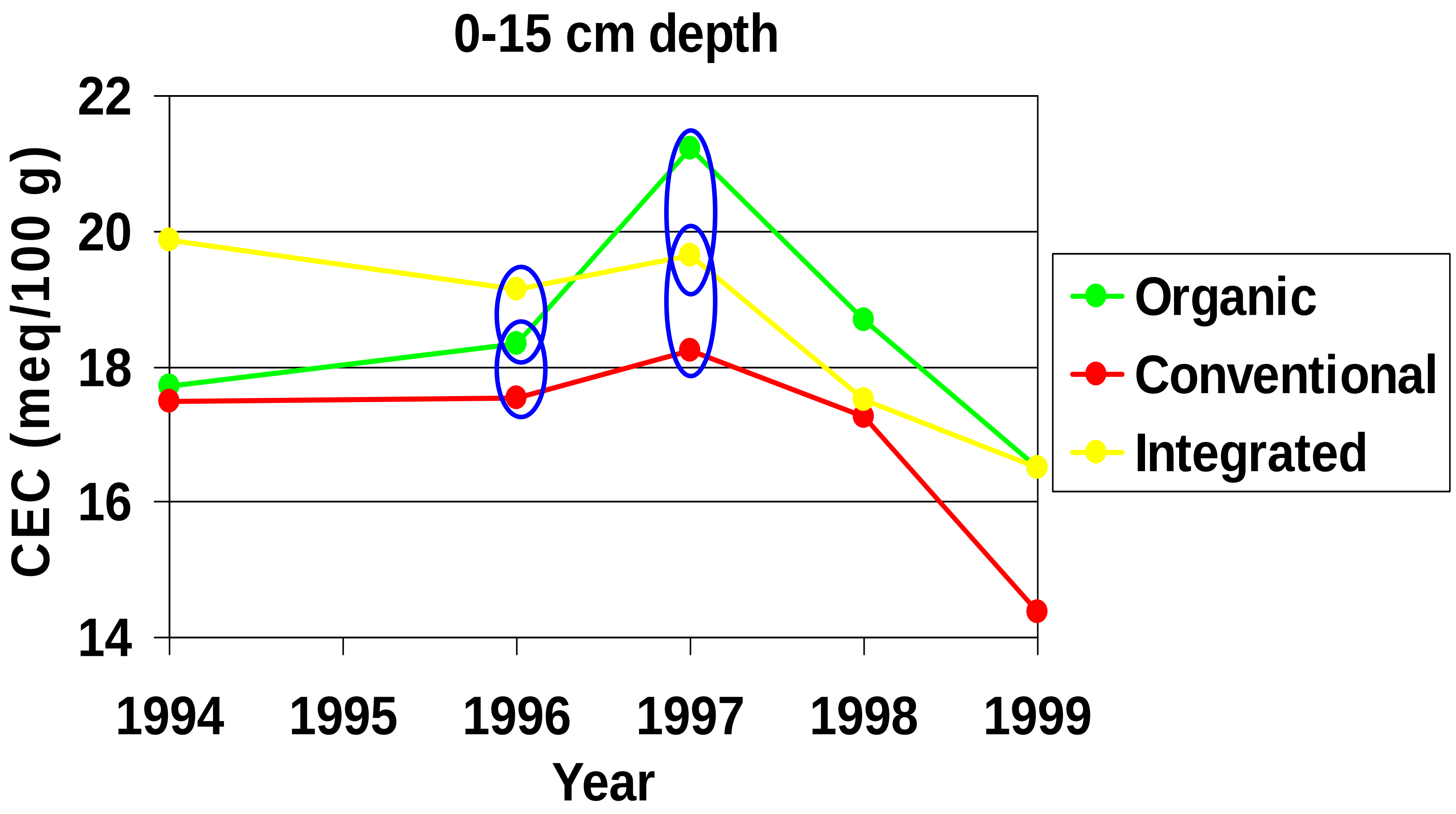
Study Characteristics

- Sandy loam texture soil
- Planted 1994 to 'Golden Delicious'/M.9
- 903 trees/A (2240 trees/ha)
- Organic, conventional & integrated
- Orchard floor management & fertilizers
  - Organic - Bark mulch & composted poultry manure
  - Conventional - Herbicides & $Ca(NO_3)_2$
  - Integrated - Bark mulch/herbicide & 50:50 compost:$Ca(NO_3)_2$

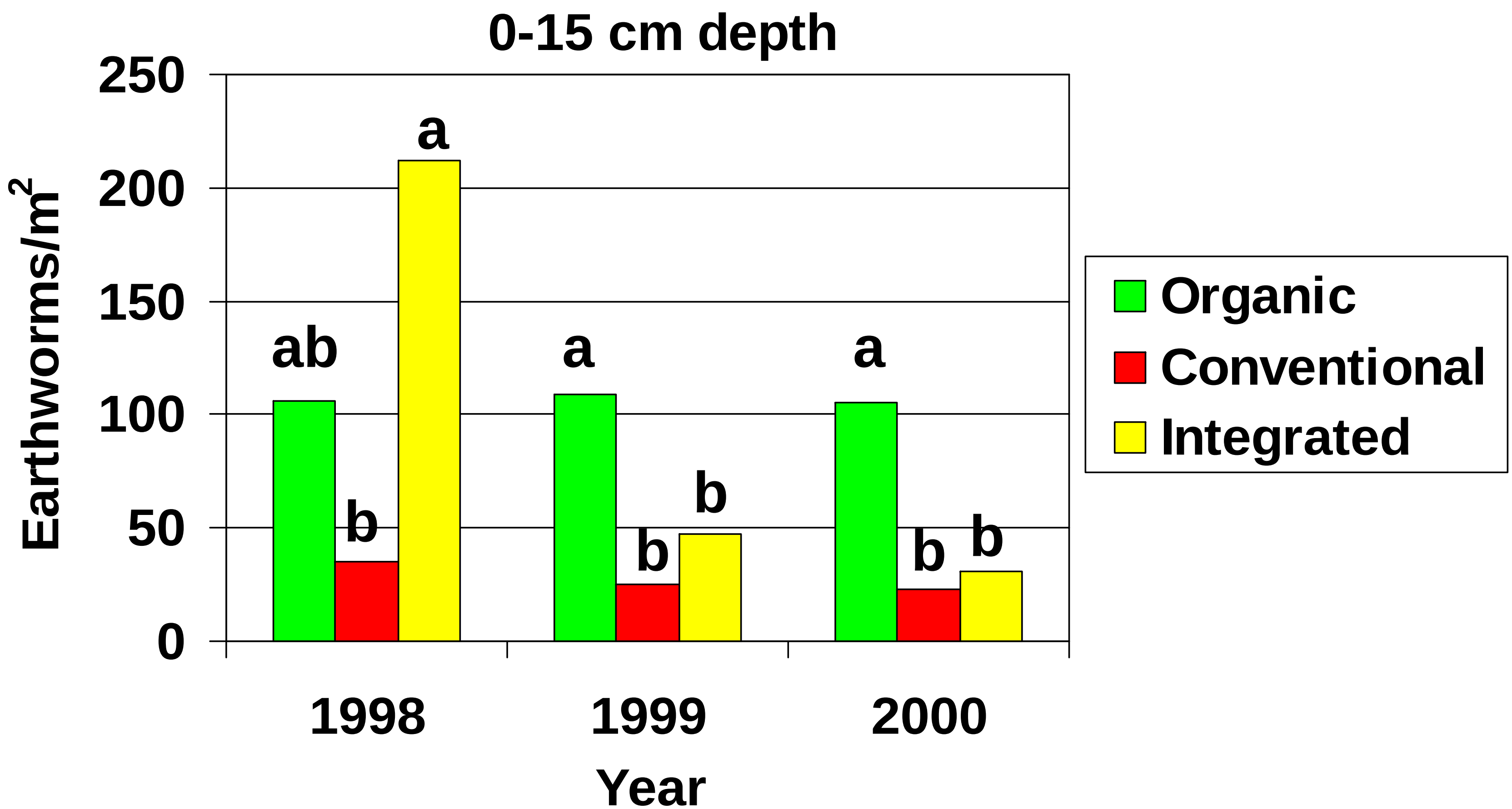
Organic Matter



Cation Exchange Capacity

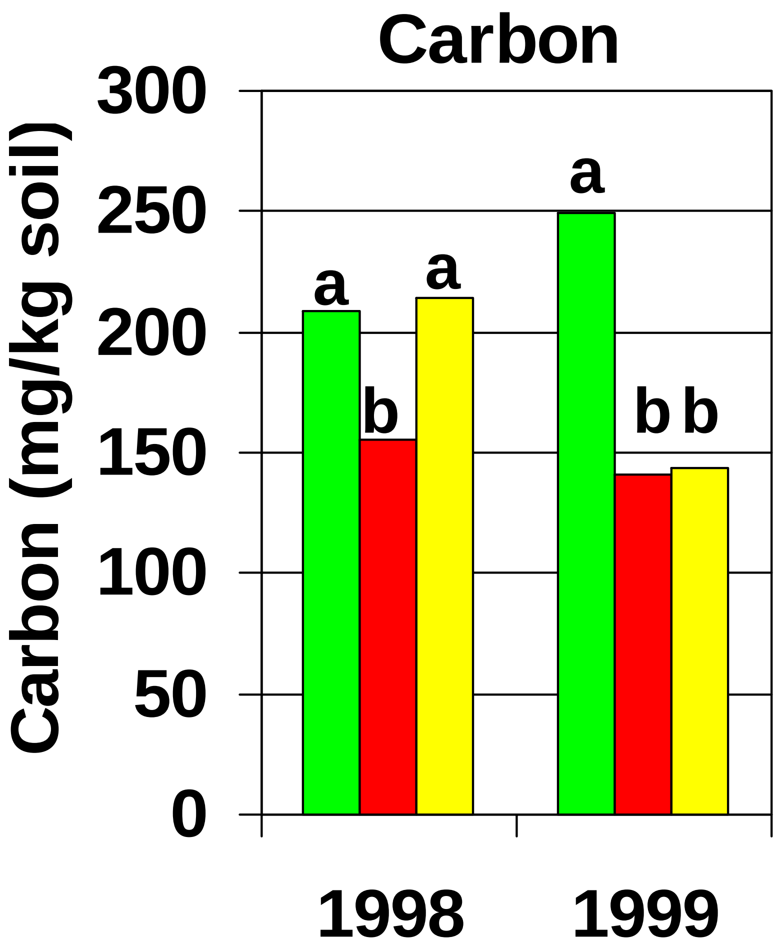


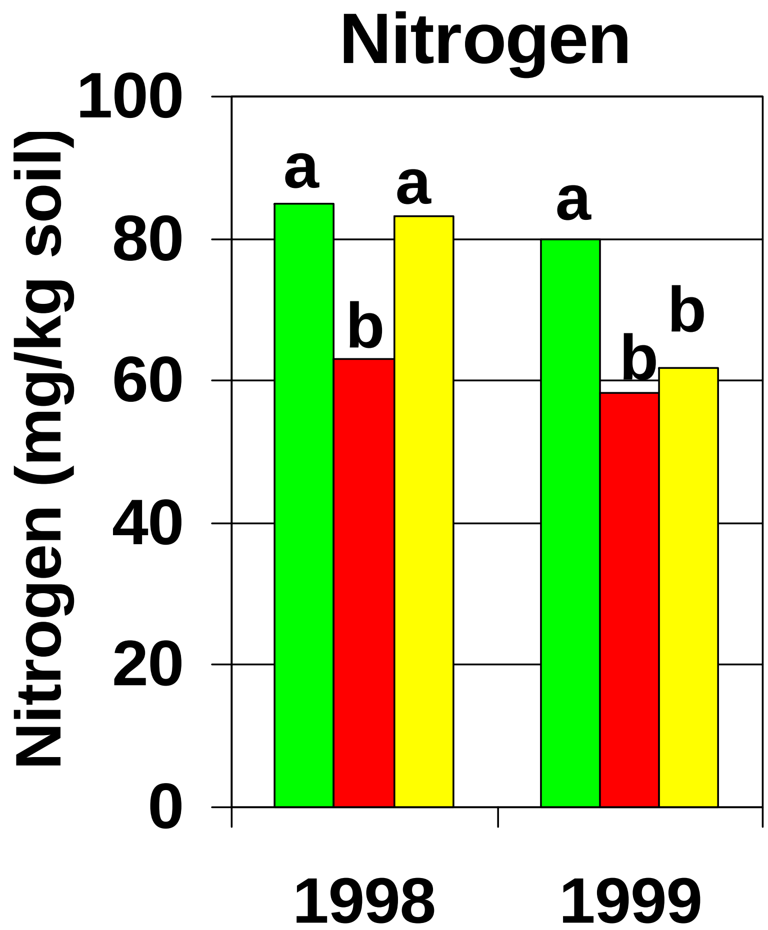
Earthworms


0-15 cm depth
Earthworms/m2
250
200
150
100
50
0
a
ab
b
a
b
b
a
b
b
1998
1999
2000
Year
Organic
Conventional
Integrated

Microbial Biomass

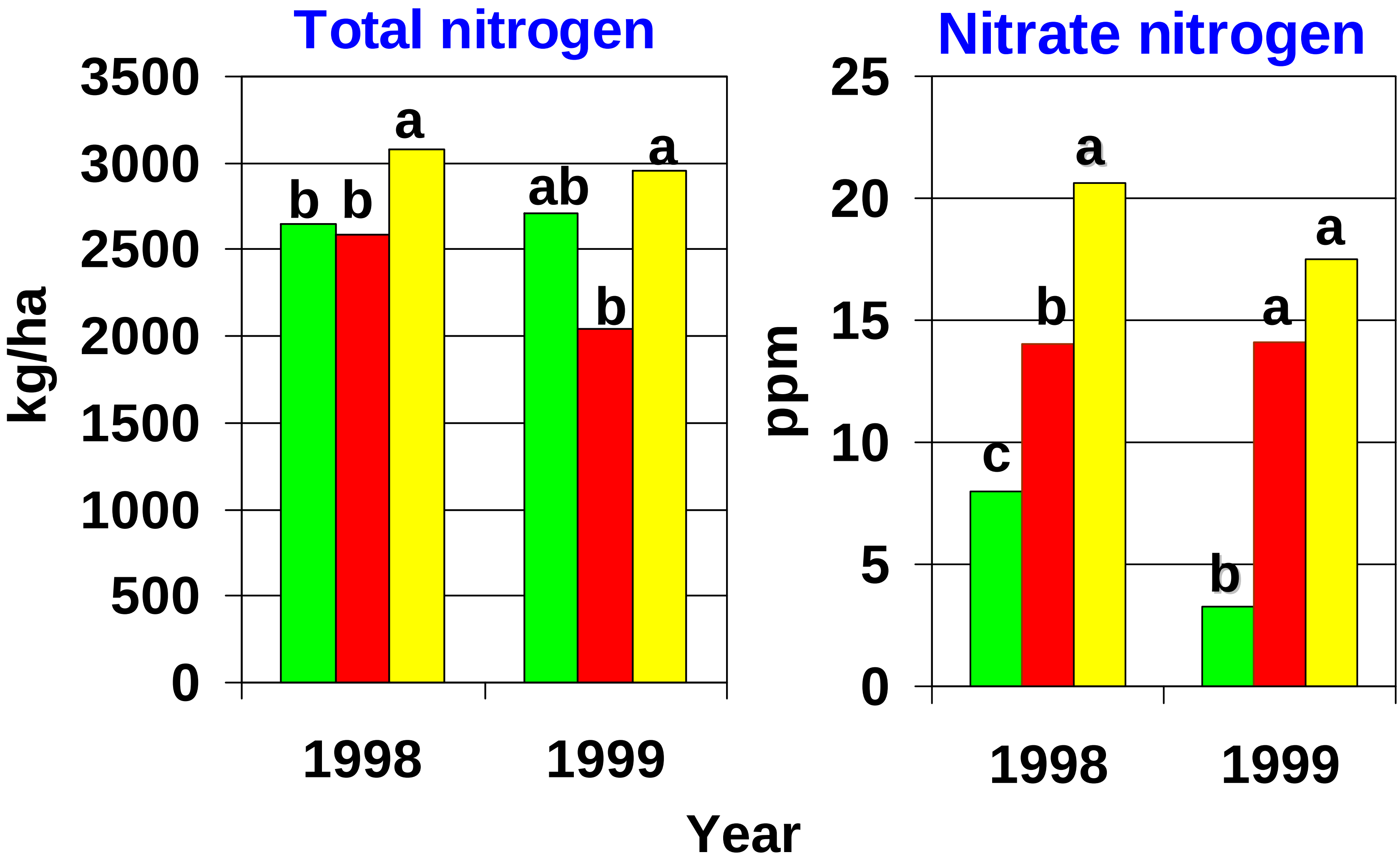
0-7.5 cm depth



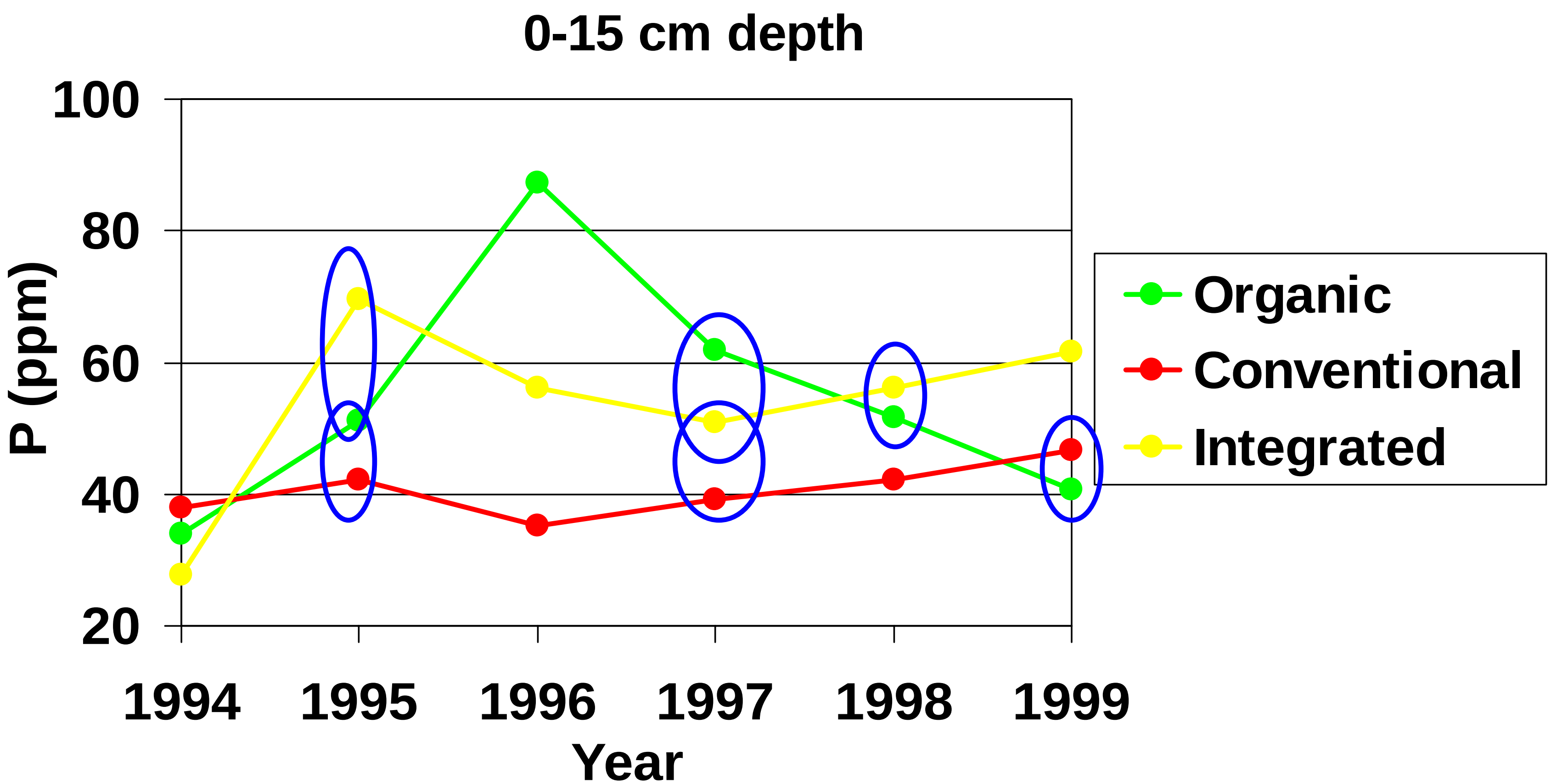


Soil Nitrogen

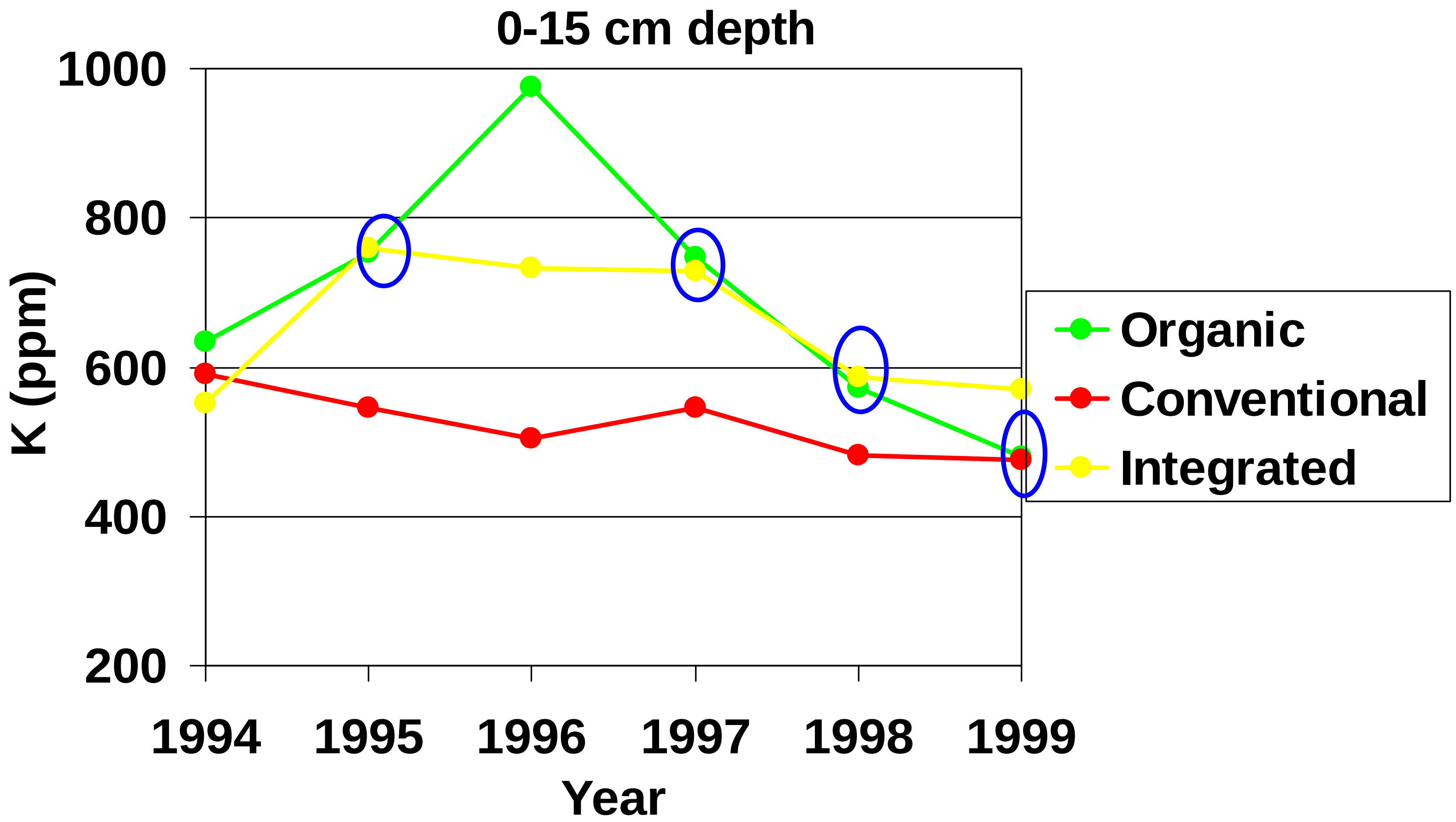
0-15 cm depth



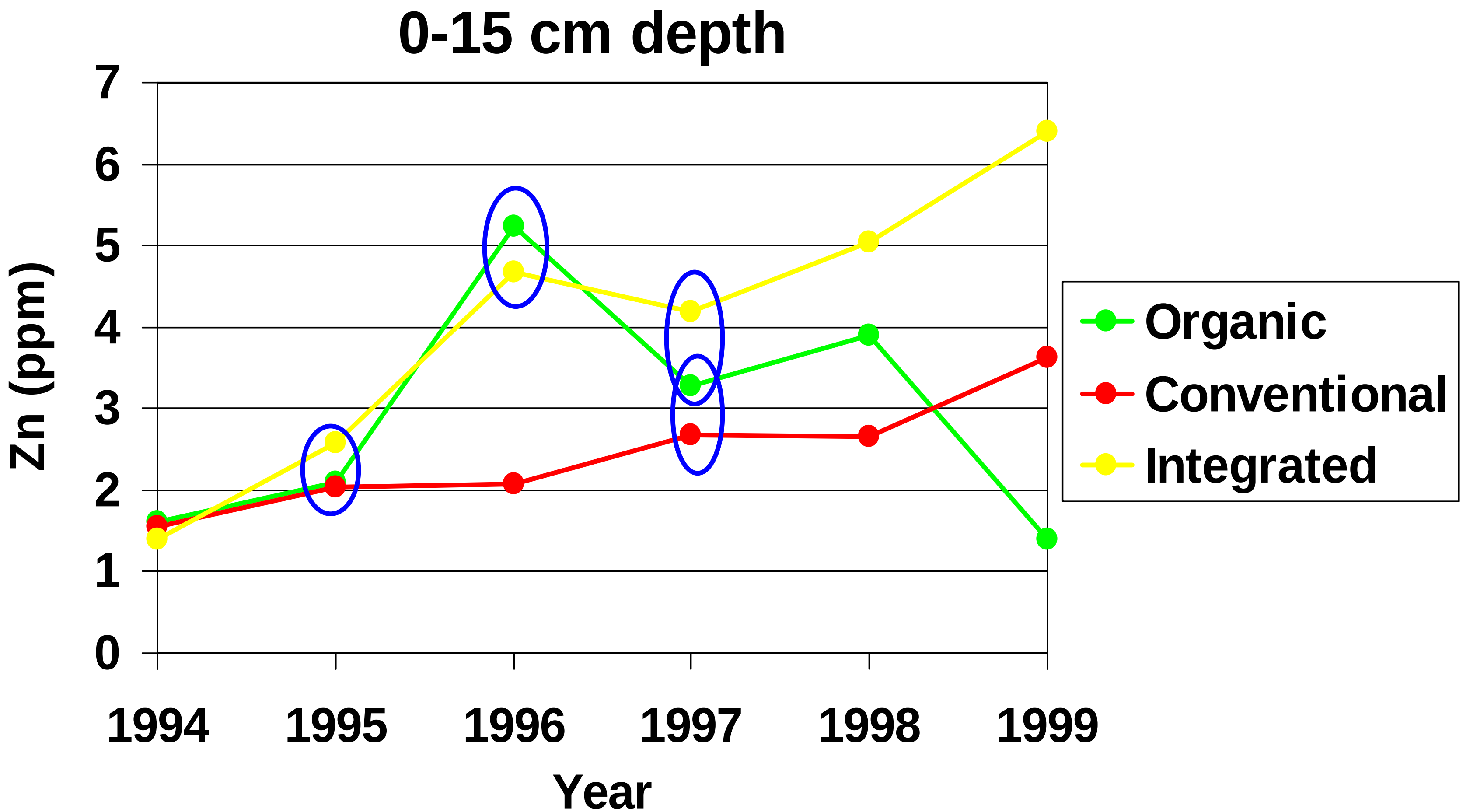
Soil Phosphorus



Soil Potassium



Soil Zinc



0-15 cm depth
Zn (ppm)
0
1
2
3
4
5
6
7
1994
1995
1996
1997
1998
1999
Year
Organic
Conventional
Integrated

Tissue Nutrient Contents

Organic vs. Conventional

- **Leaf**

  N - no differences

  P - slightly higher in organic

  K - slightly higher in conventional

  Ca, Mg, B - no or slight differences

  Zn - slightly lower in organic

- **Fruit**

  Slightly lower N, P & B in organic (lower N:Ca)

Conclusions

- **Soil nutrient cycling depends on physical weathering & biological activity**
- **Multiple pathways of nutrient uptake**
- **Root activity poorly understood**
- **Spatial & temporal changes in tissue concentration of multiple nutrients**
- **Foliar nutrient uptake inefficient**
- **Most complex resource to manage**