Mineral Nutrition & Fertilizers

Unique Nutrient Characteristics of Perennial Fruit Crops

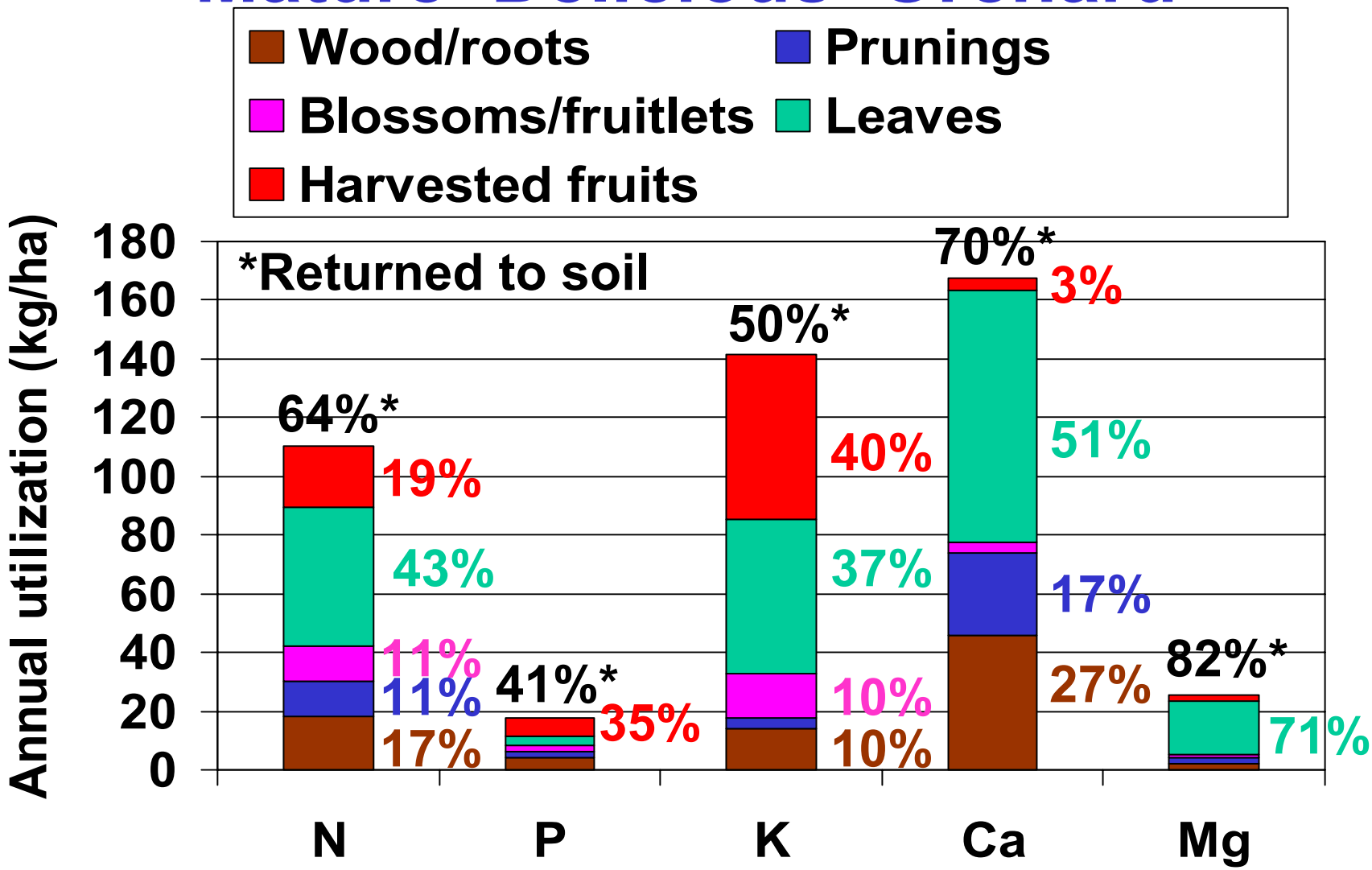
- **Nutrients are removed from the orchard in fruit at harvest**
- **Nutrients are retained as reserves in dormant tissues (buds, bark & roots) for re-mobilization in the spring**
- **Nutrients are re-cycled into the soil as thinned flowers & fruits, leaf fall & prunings**

High Nutrient Demand Periods

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

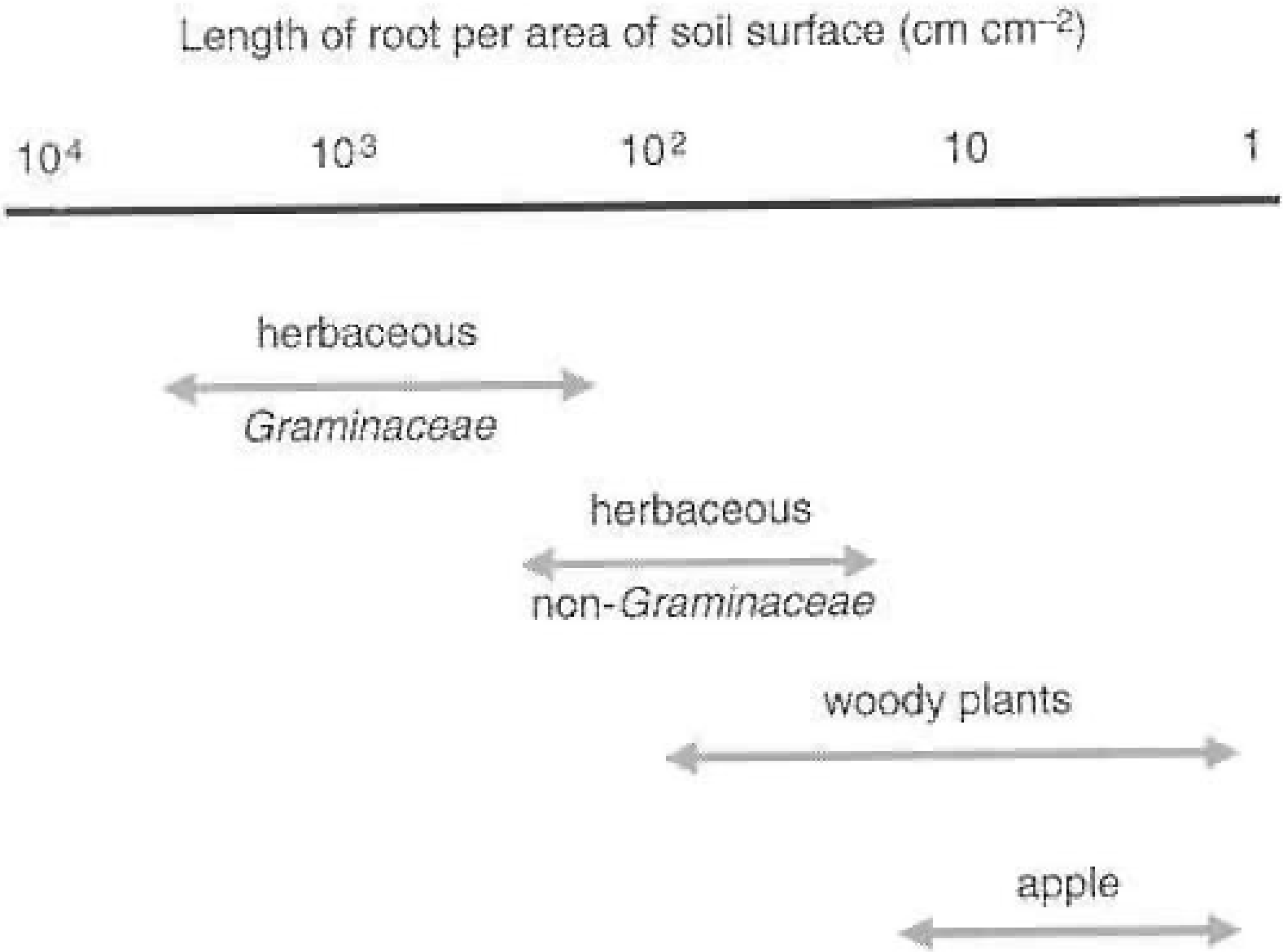
Nutrient Utilization

Mature 'Delicious' Orchard



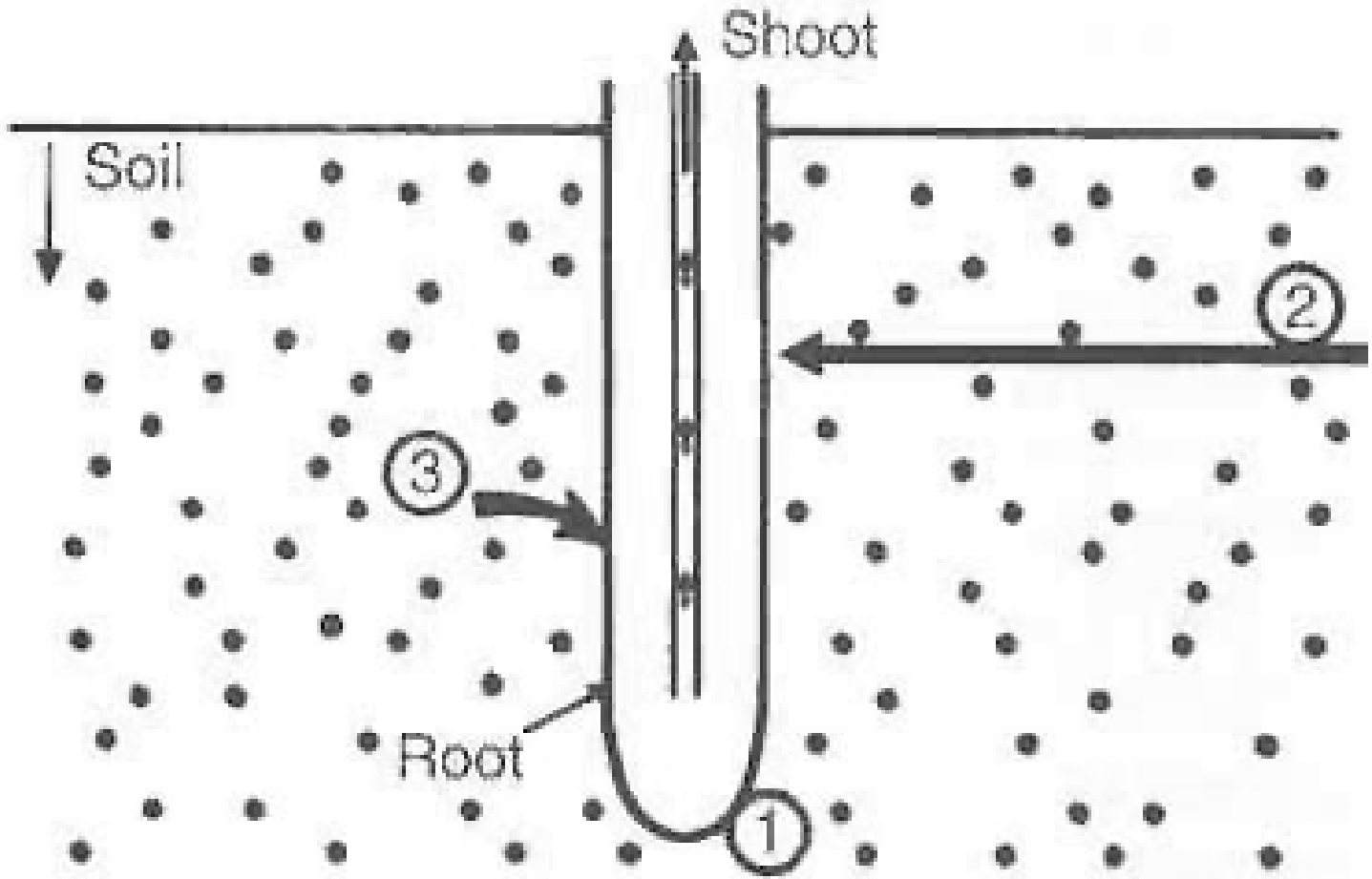
Batjer et al, 1952

Root Densities

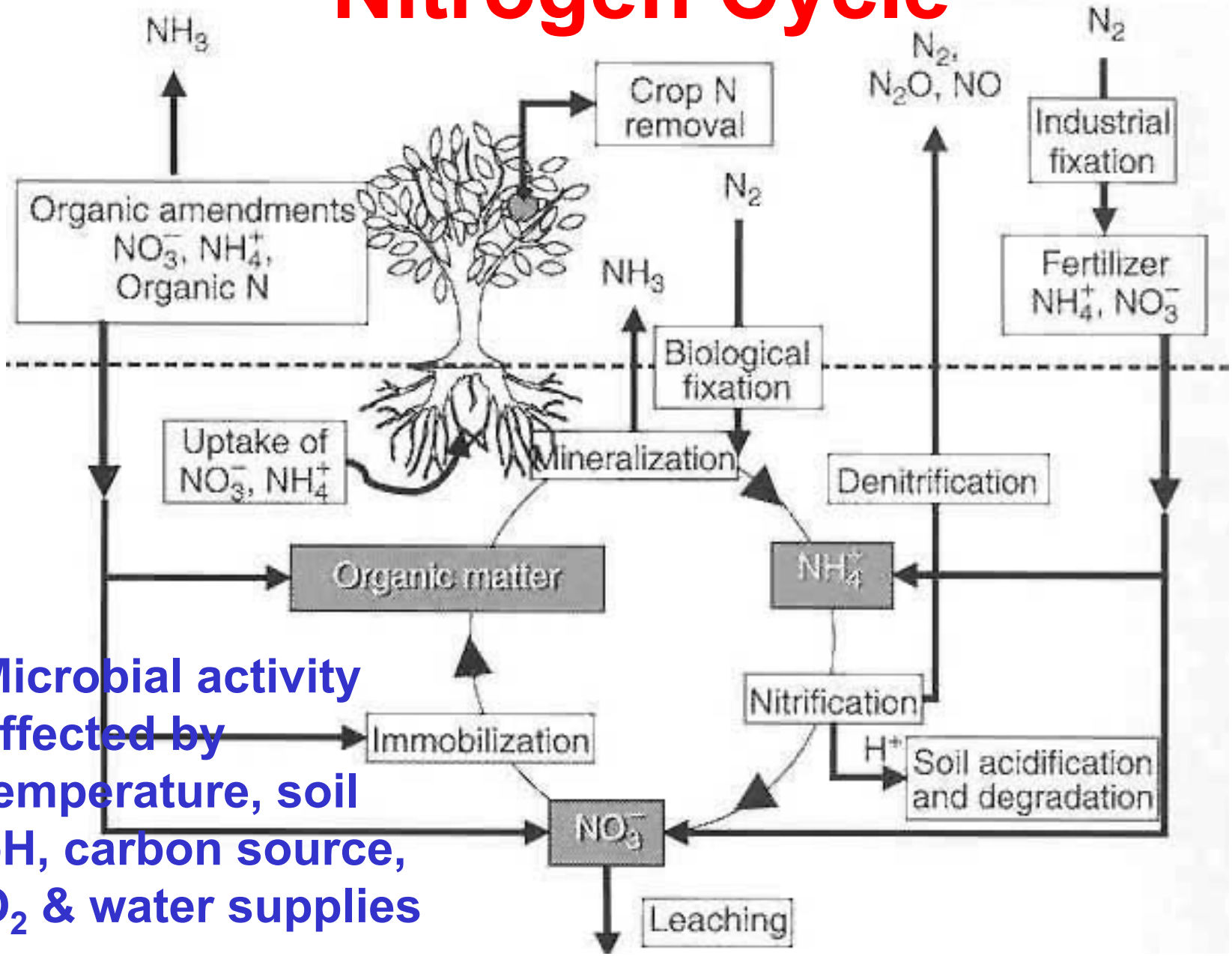


Nutrient Uptake Pathways

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, soil pH, carbon source, O_2 & water supplies

Nitrogen Fixation

Root nodules fix N

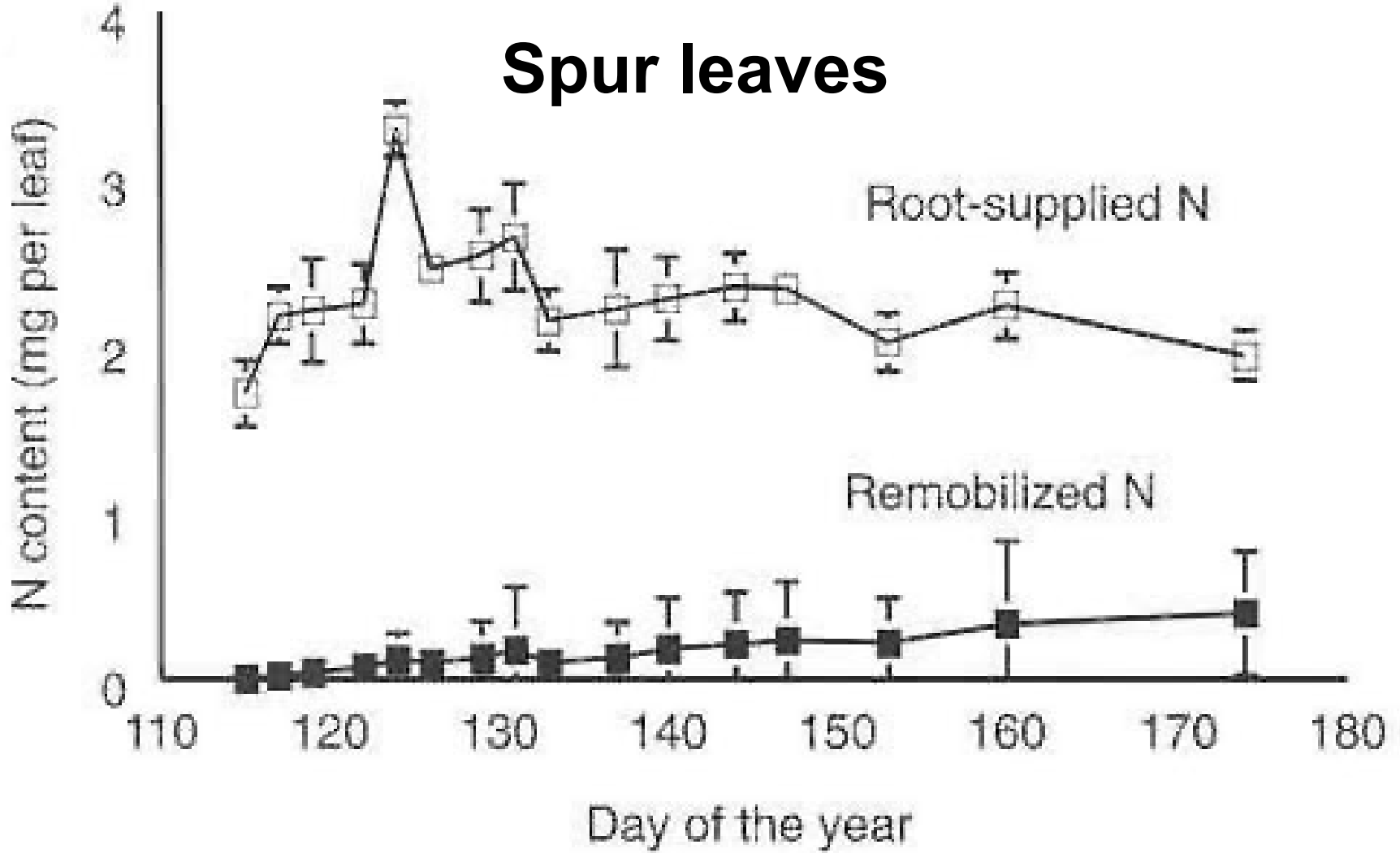
Rye grass & red clover
15-105 kg N/ha/year

Better nutrient cycling

Nitrogen Uptake & Utilization

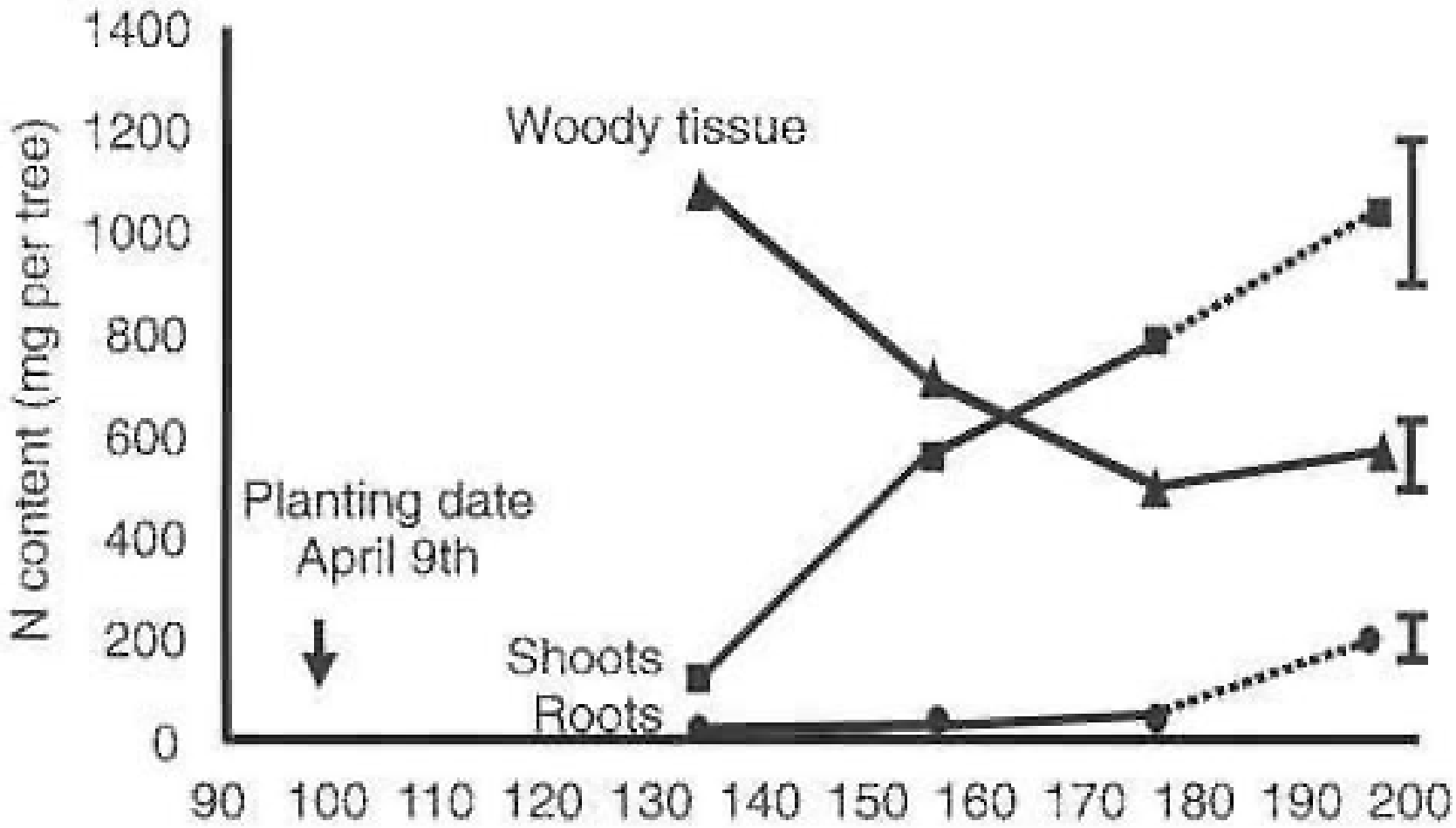
- NO_3^- or NH_4^+ ions absorbed by roots
- NO_3^- reduced to NH_4^+ by nitrate reductase
- NH_4^+ assimilated into amino acid glutamine
- Glutamine converted to amino acids glutamate & aspartate
- 90% of N transported in xylem are amino acids
- Leaves are major sinks for amino acids, which are converted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

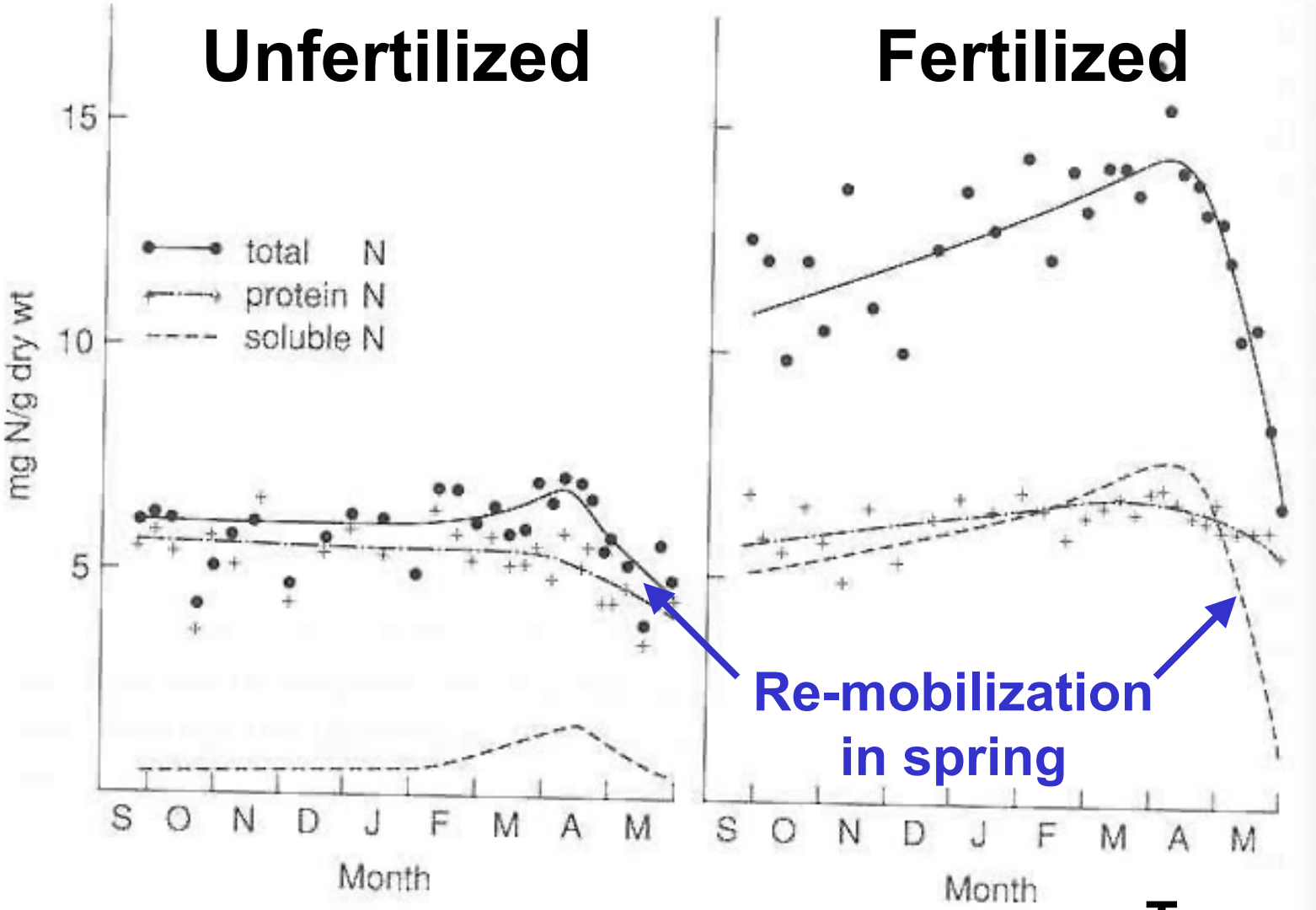
Re-Mobilized Nitrogen
New 'Golden Delicious'/M.9 trees



Neilsen & Neilsen, 2003

Protein & Soluble Nitrogen

One-year-old M.7 apple

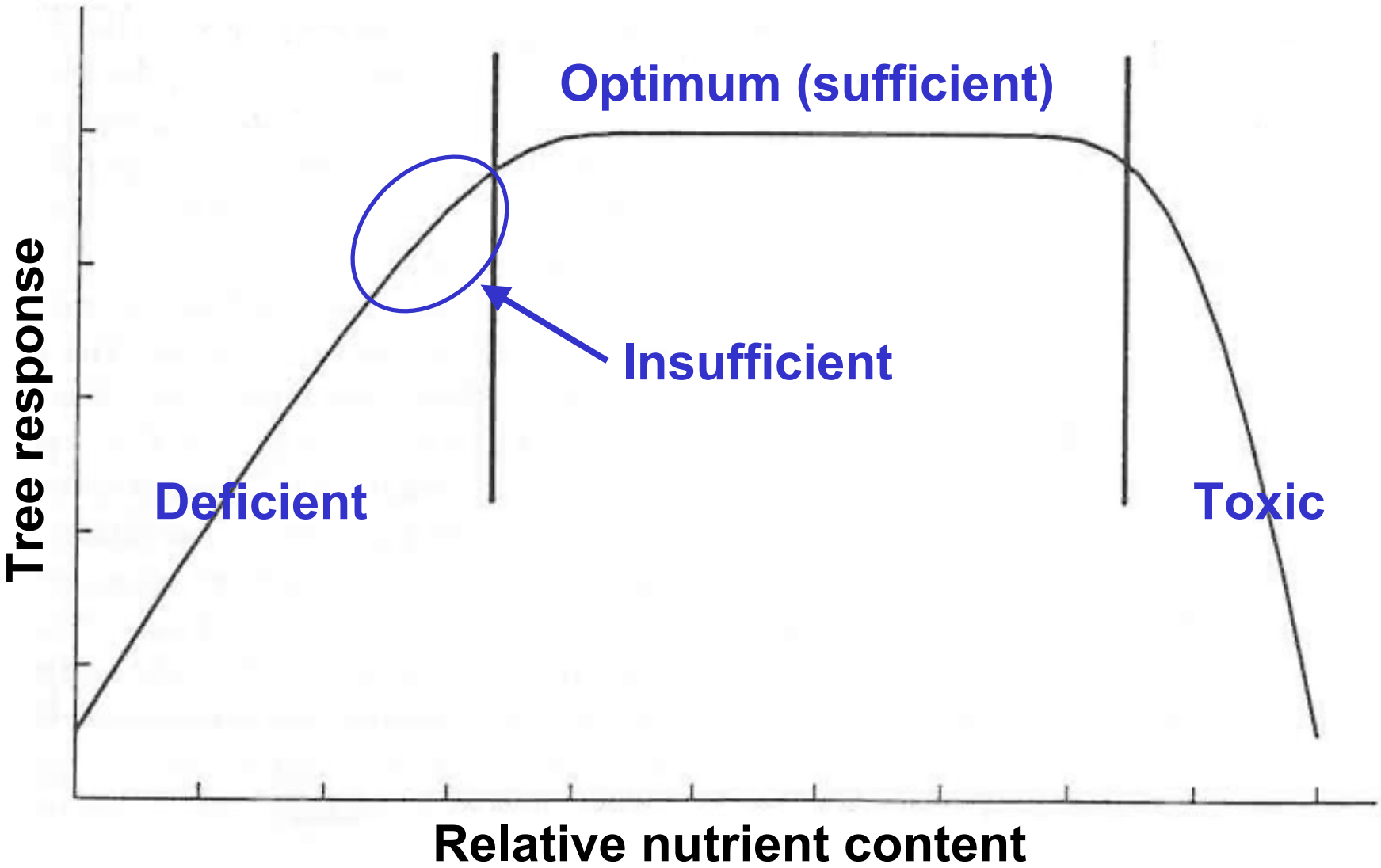


Tromp, 1983

Levels of Nutrient Status

- **Deficient:** visual symptoms
- **Insufficient:** no visual deficiency 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 Concentration

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

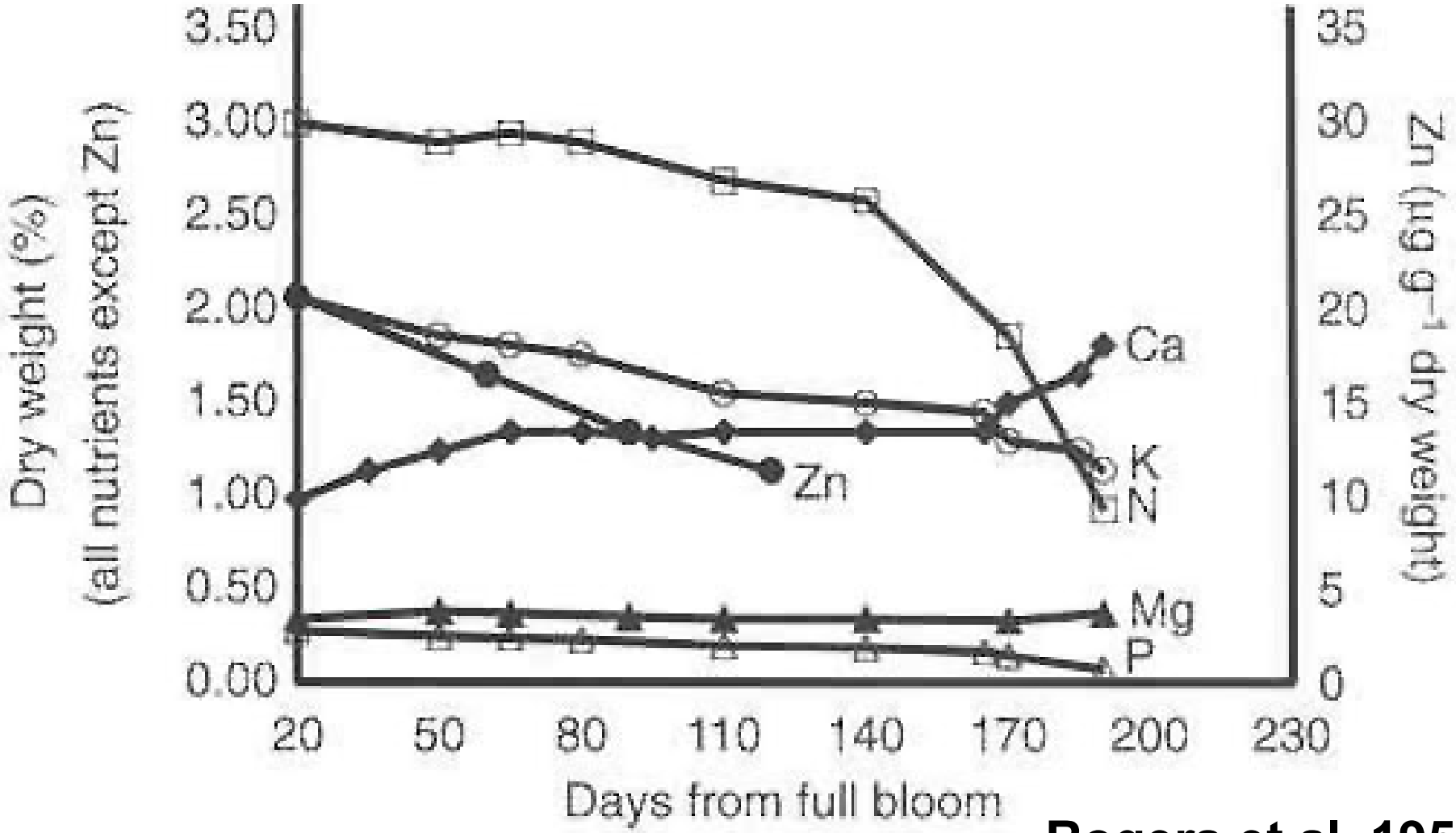
- **Soil analysis:** **At planting, then every 3-5 years, or more frequently in suspected problem areas**
- **Tissue analysis:** **Every year because it integrates soil nutrient availability & uptake & utilization by tree; usually reported as concentration (%DW or ppm)**

  Leaves (mid-shoot) sampled in late July to early August

  Fruit sampled a few weeks before harvest

Mid-Shoot Sampling

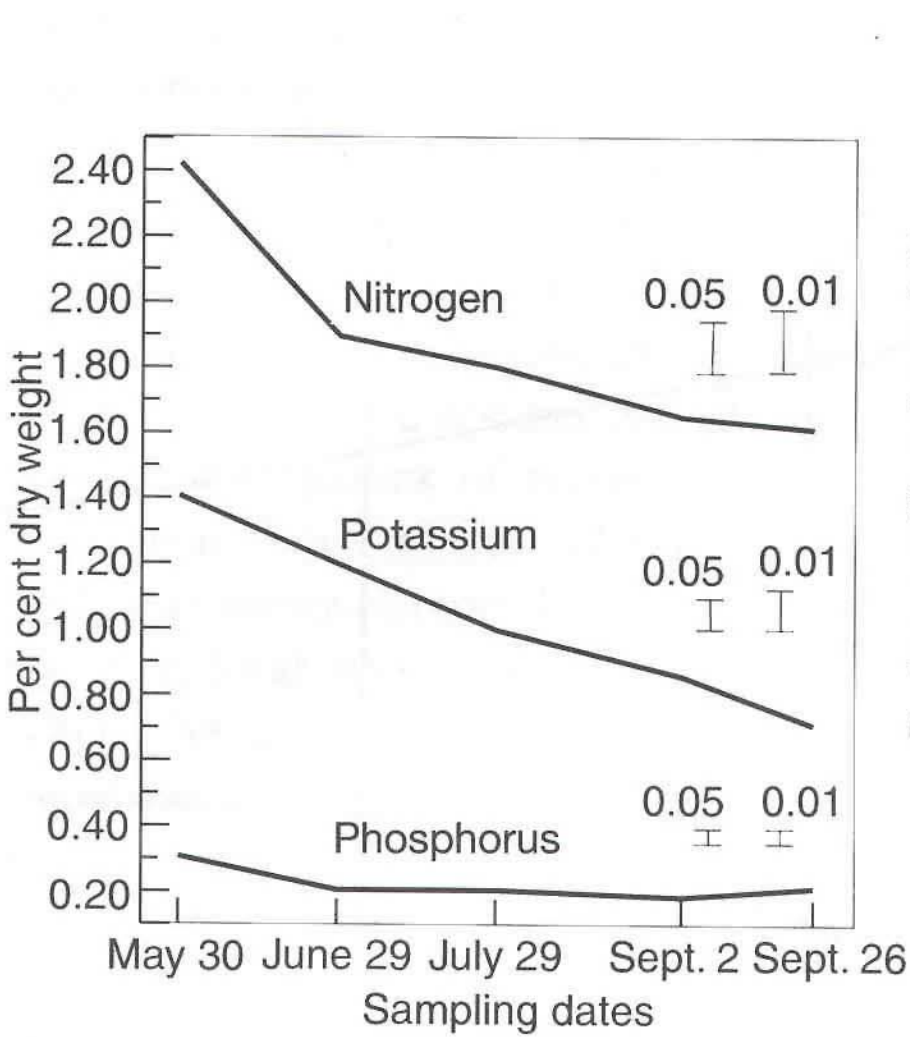
Seasonal Nutrients
‘Delicious’ Apple Leaves

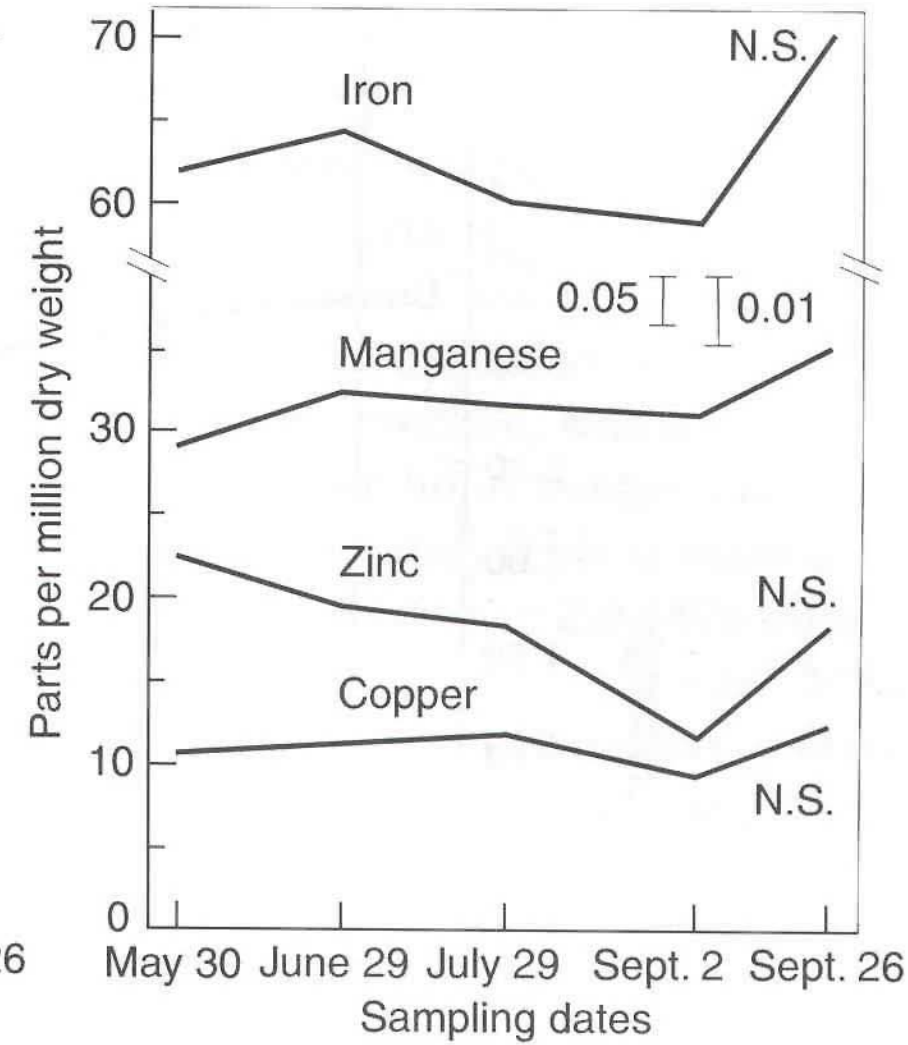


Rogers et al, 1953

Seasonal Nutrients

‘Bing’ Sweet Cherry Leaves





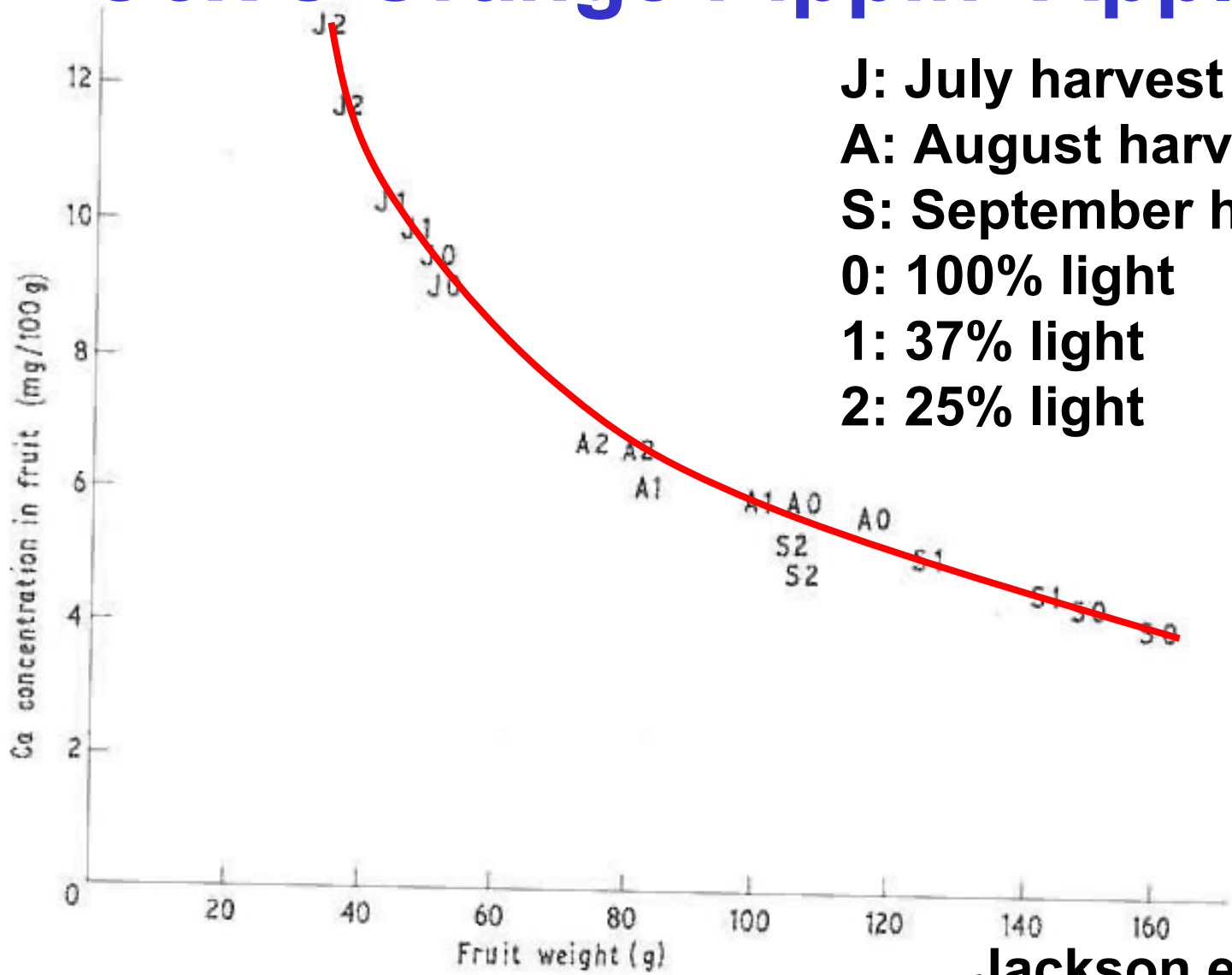
Christensen & Walker, 1964

Variables in Nutrient Content

- **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

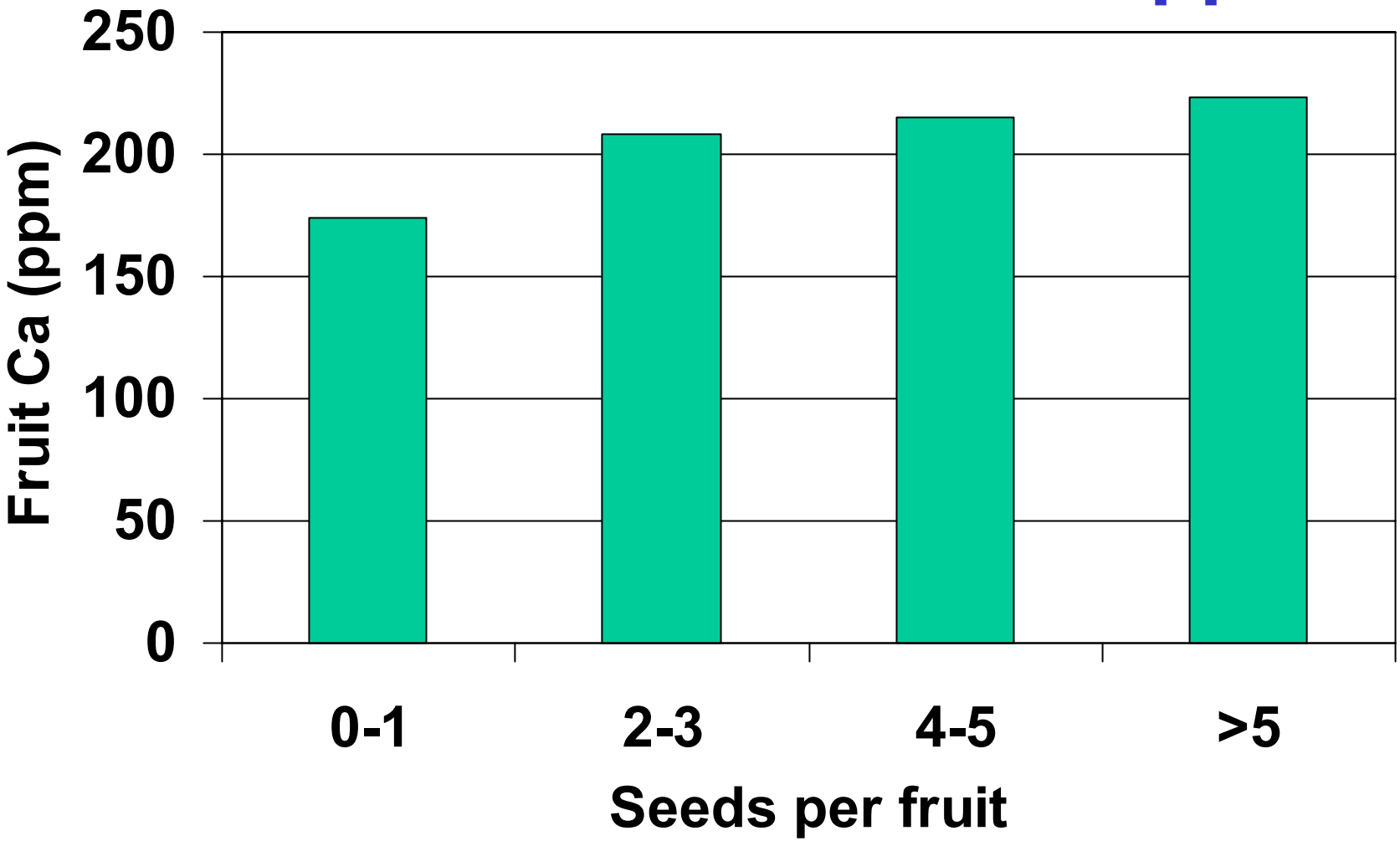


J: July harvest
A: August harvest
S: September harvest
0: 100% light
1: 37% light
2: 25% light

Jackson et al, 1977

Seeds & Calcium

'Richared Delicious' Apple



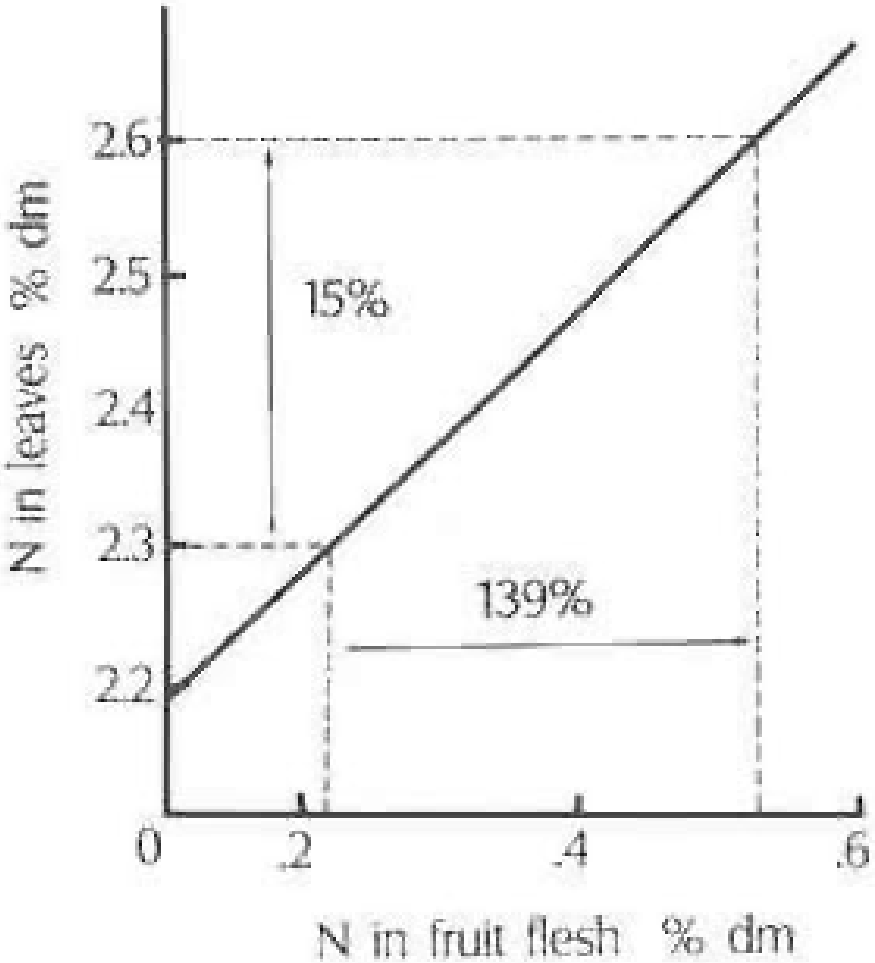
Bramlage et al, 1990

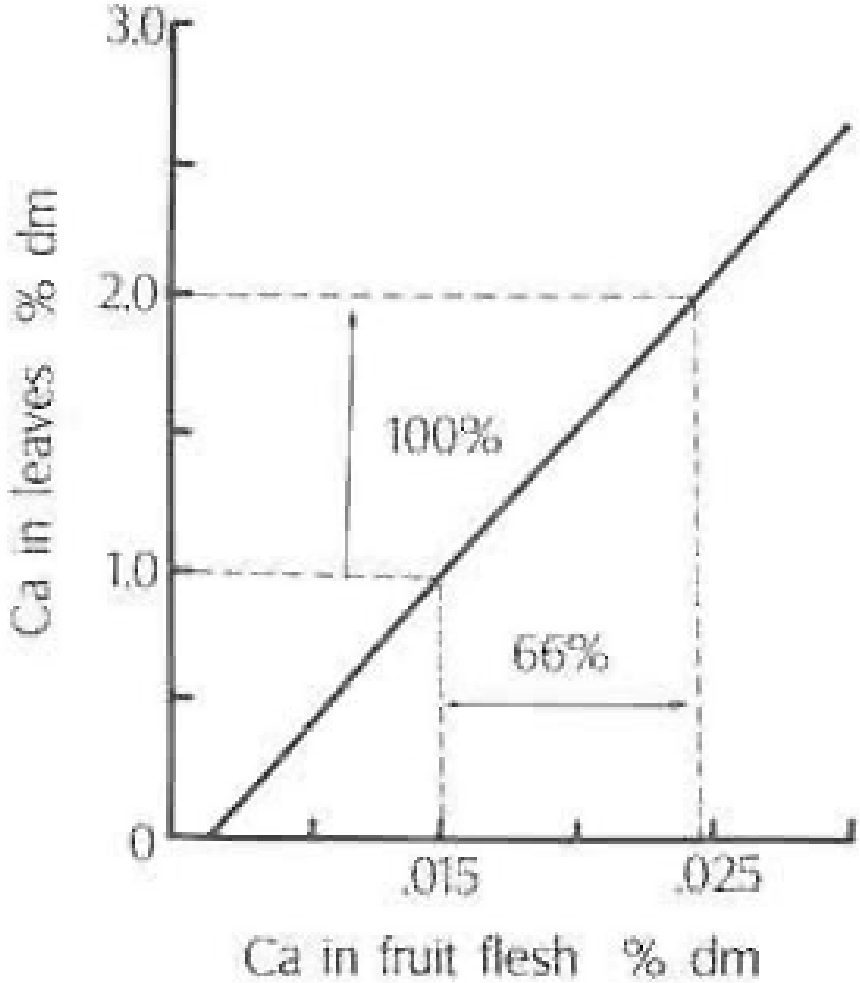
Nutrient Ratios

- **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**

Nitrogen & Calcium

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





Shear, 1974

Nutrient Requirements

- **Nitrogen:** applications usually needed every year
  - ↑ vegetative growth, flowering, fruit set, fruit growth
  - ↓ fruit color, accentuates Ca-related disorders
- **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, transmembrane pH gradient in photosynthesis, osmoregulation, stomatal conductance
  - Very abundant in soil & very mobile in phloem
  - Application not usually needed, may improve fruit color

- **Calcium: constituent of cell walls & regulatory signal for metabolism**

  Critical for fruit quality & storability

  Ca-related disorders: bitter pit, watercore, cork spot, lentical 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

- **Iron: constituent of complex for electron transport**

  Lime-induced chlorosis in calcareous ($Ca[CO_3]_2$) soils with high pH; aggravated by excess irrigation, especially in shallow soils

- **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

Ground Applications

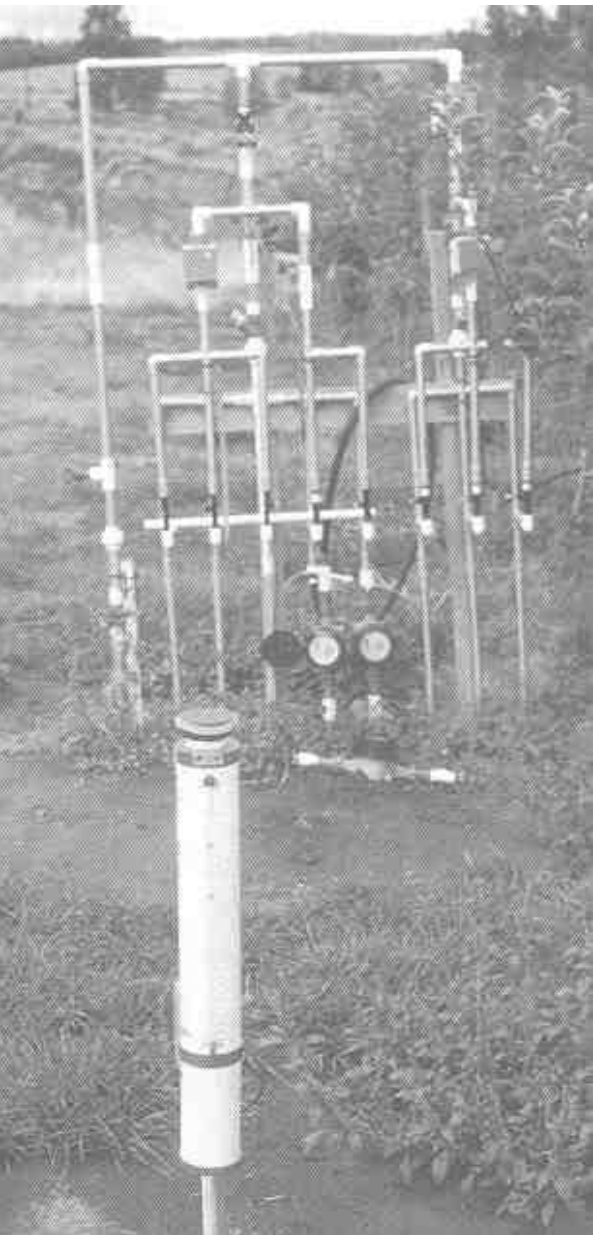
- **Requires root activity (usually spring & autumn) for nutrient uptake**
- **Usually N, P, K**
- **Single vs. split applications:**

  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

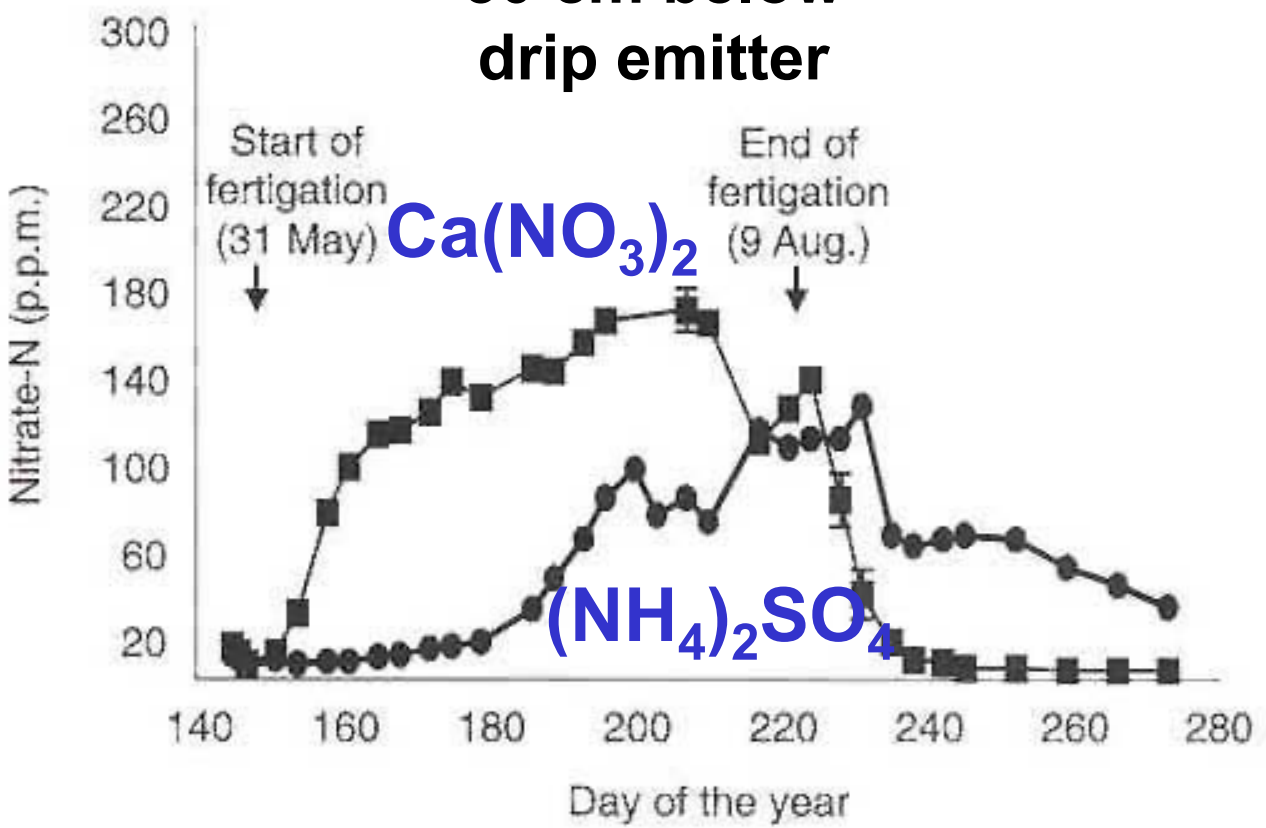
  Split spring + autumn applications: ↑N reserves in roots, which supplies more N for budbreak, bloom & fruit set

- **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

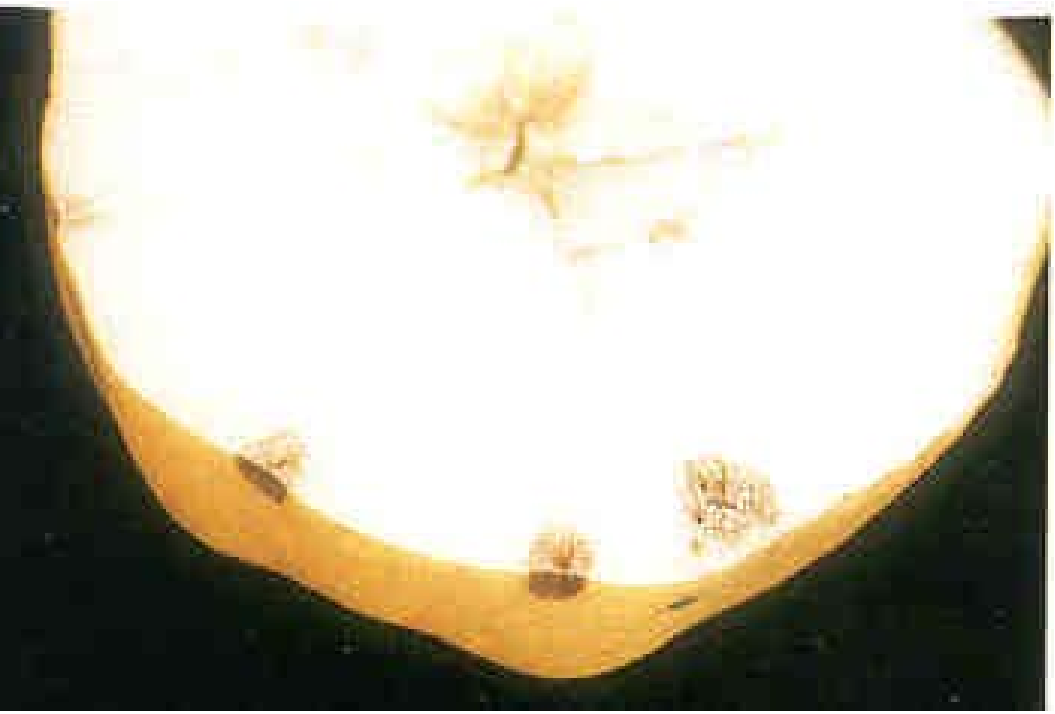
- **Healthy leaves absorb more nutrients**
- **Urea: Post-harvest applications increase N reserves in bark, which are more available for budbreak, bloom & fruit set**
- **Nutrients immobile in soil (Fe & Zn) or plant (Ca & B)**

  Zinc: dormant or delayed dormant

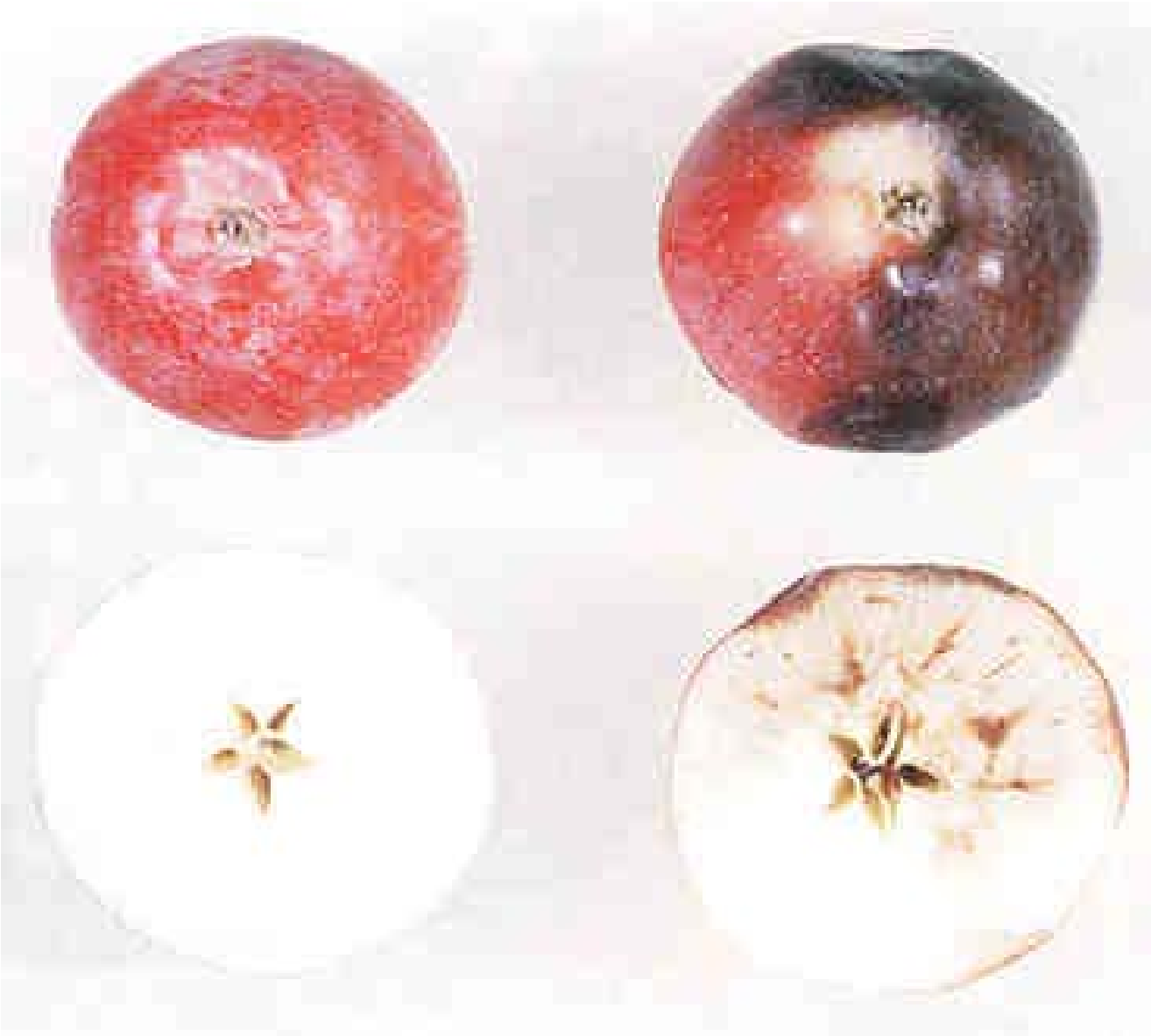
  Boron: pre-pink or pink stage

  Calcium & Iron: post-bloom to harvest

Bitter Pit of Apple

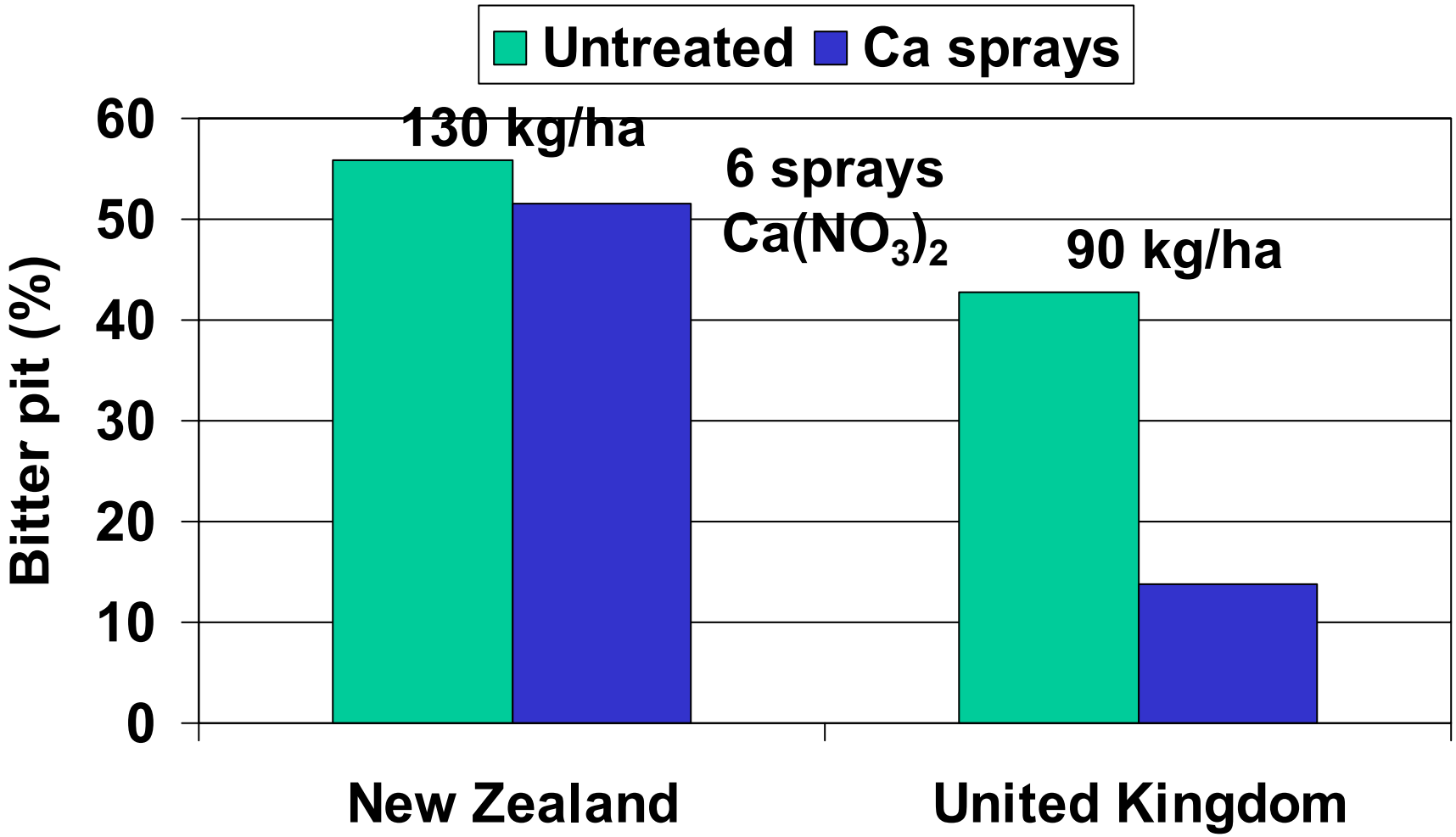


Internal Breakdown of Apple



Calcium & Bitter Pit

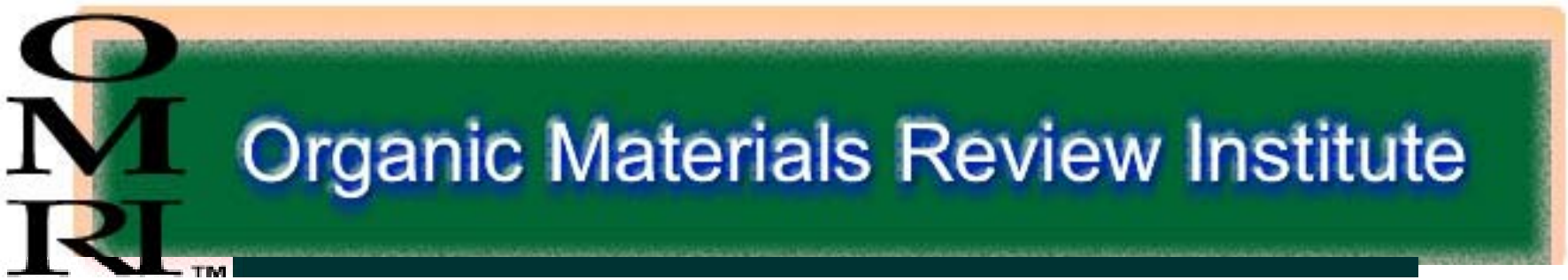
'Cox's Orange Pippin' Apple



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
- Micronutients:
  - Soluble boron
  - Zinc, copper, iron & manganese sulfates, carbonates, oxides or 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)

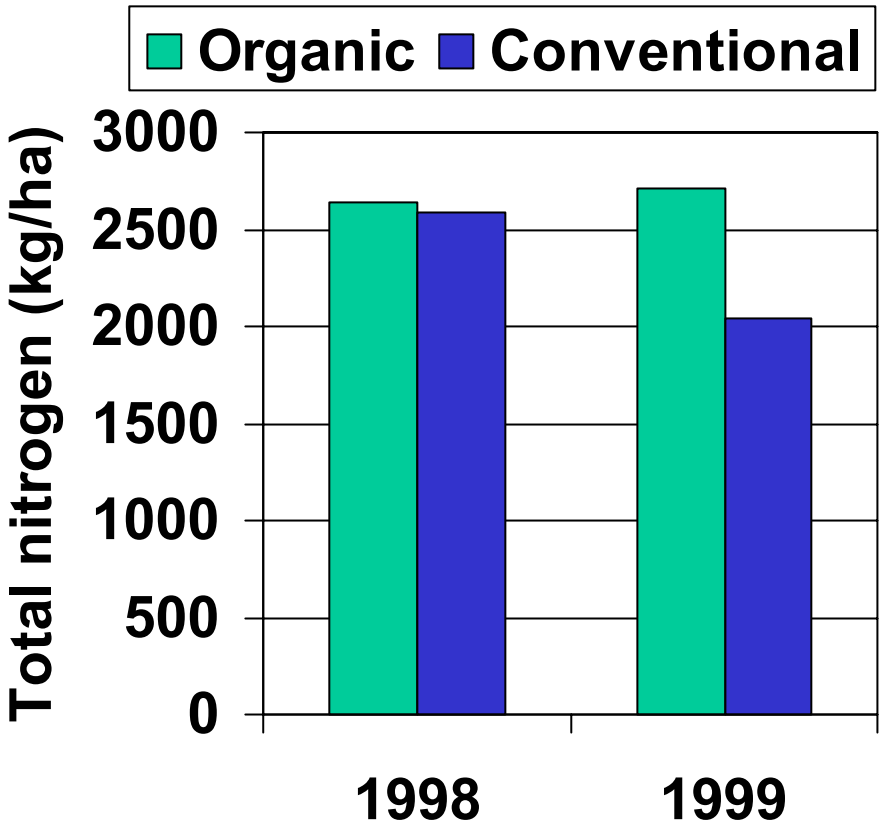
Organic Amendments
Carbon:Nitrogen Ratio

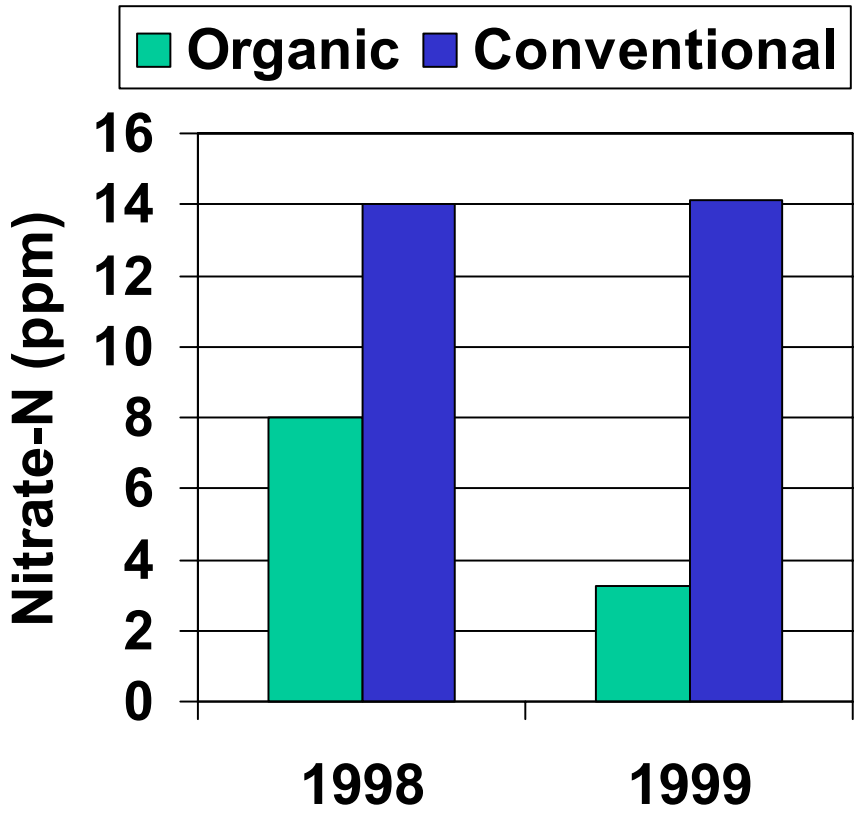
• **Low**	**15:1–20:1**	**Releases N rapidly**
legume		**(Excess N?)**
• **Medium**	**20:1–30:1**	**Intermediate**
mustard		
• **High**	**40:1–80:1**	**Releases N slowly**
grass		**(Ties up N?)**

Soil Nitrogen

Organic vs. Conventional

‘Golden Delicious’/M.9





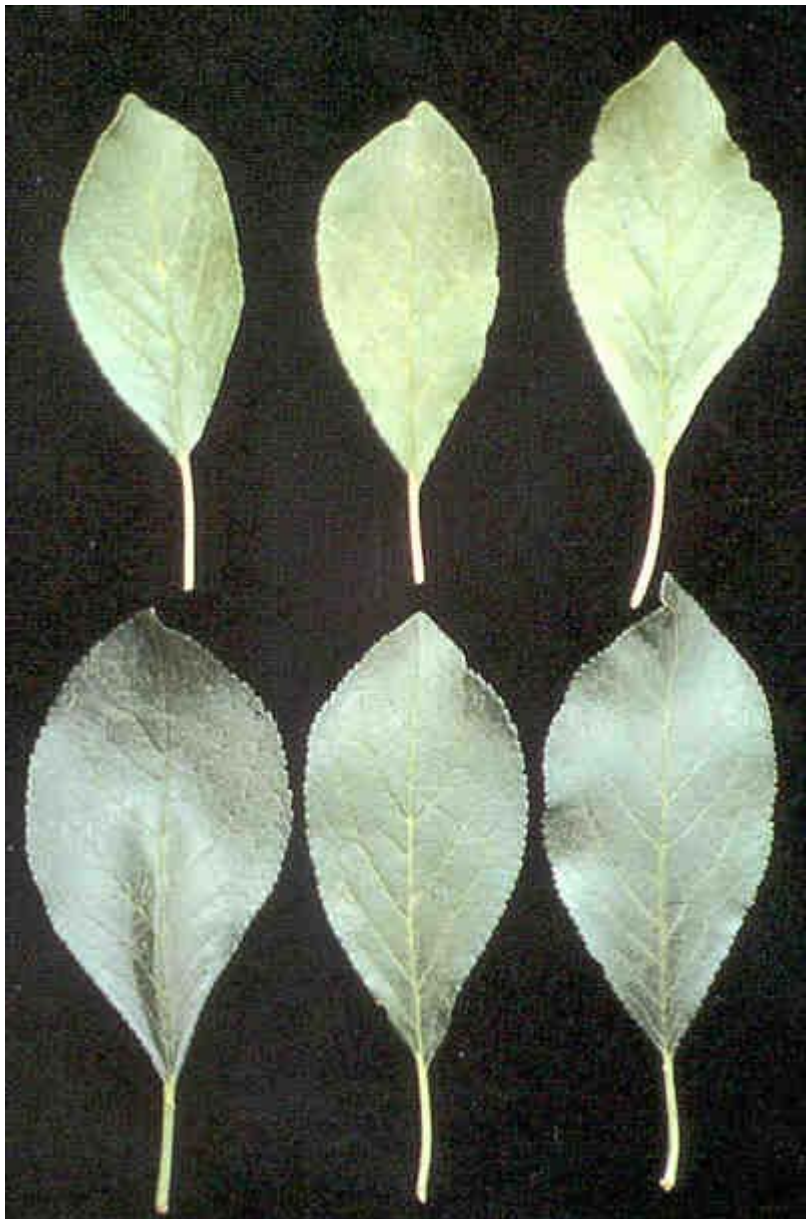
Reganold et al, 2001

Nitrogen Deficiency

Prune

Deficient

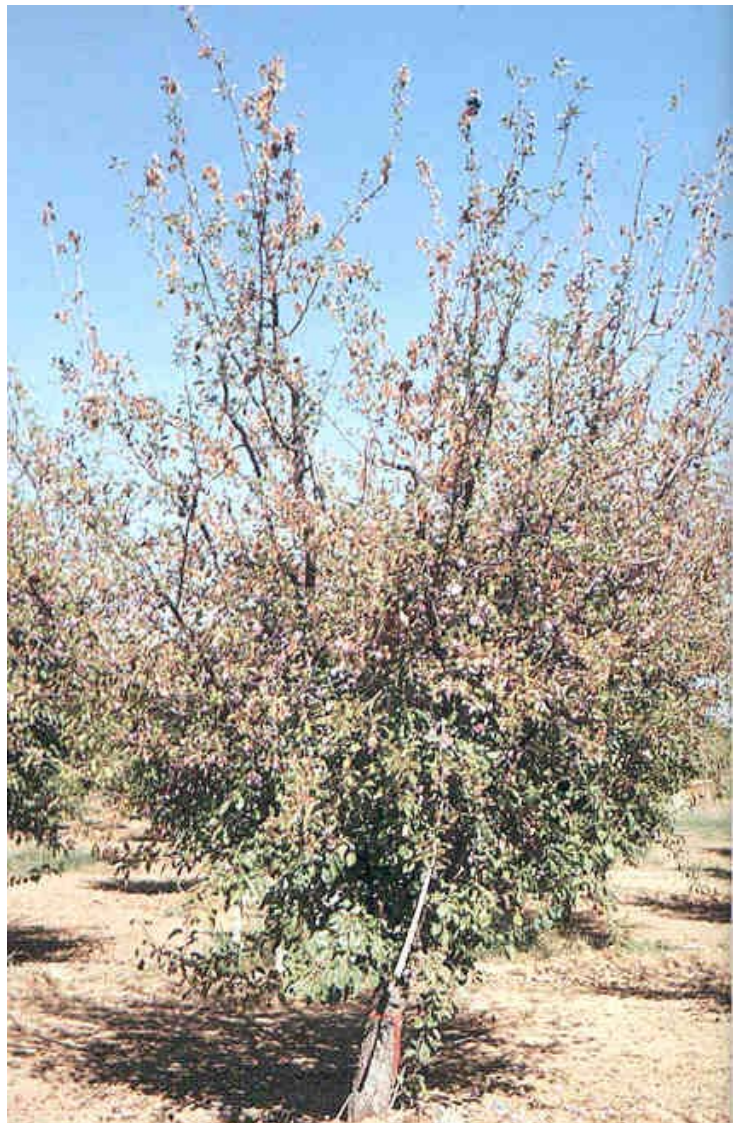
Sufficient



Potassium Deficiency

Apple

Prune



Magnesium Deficiency

Apple

Prune

Iron Deficiency

Apple

Prune

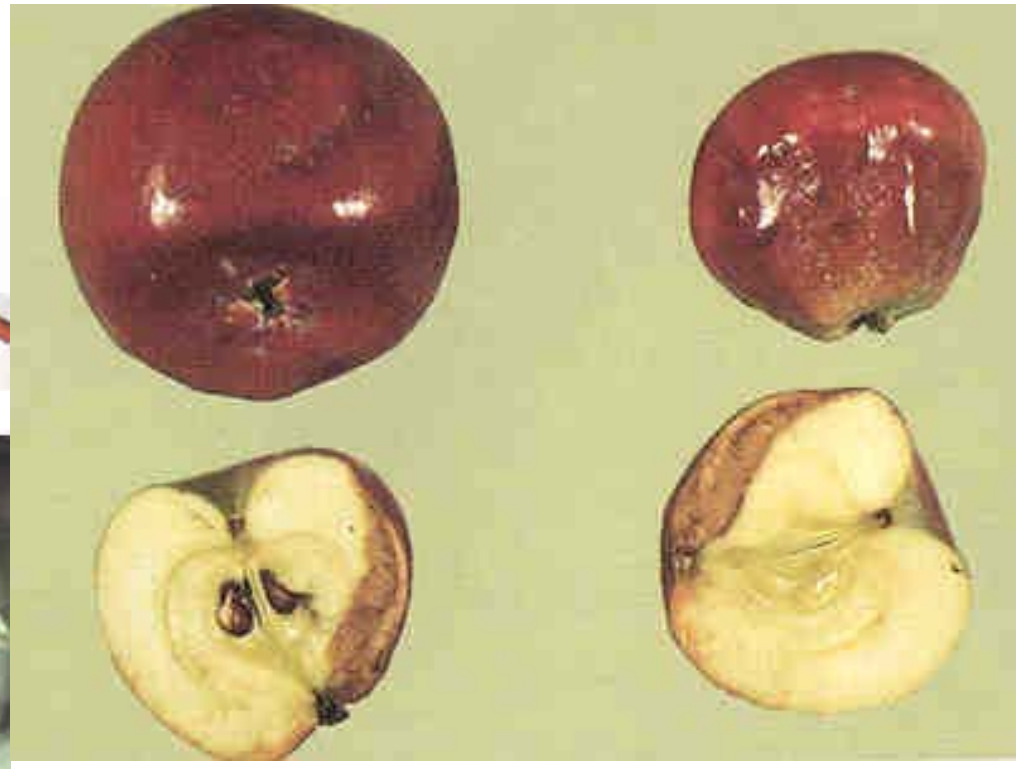
Zinc Deficiency

Apple

Peach

Prune

Boron Deficiency of Apple



Boron Toxicity of Apple