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Healthy Soils in the Orchard

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Outline

- Definition and principles
- Importance of organic matter
- Measuring soil quality (or trying to)
- Application to orchards
- Conclusions

Why Soil Matters

Key functions in crops

Physical

- Support – rooting, machine traction
- Water – infiltration, movement, storage
- Temperature

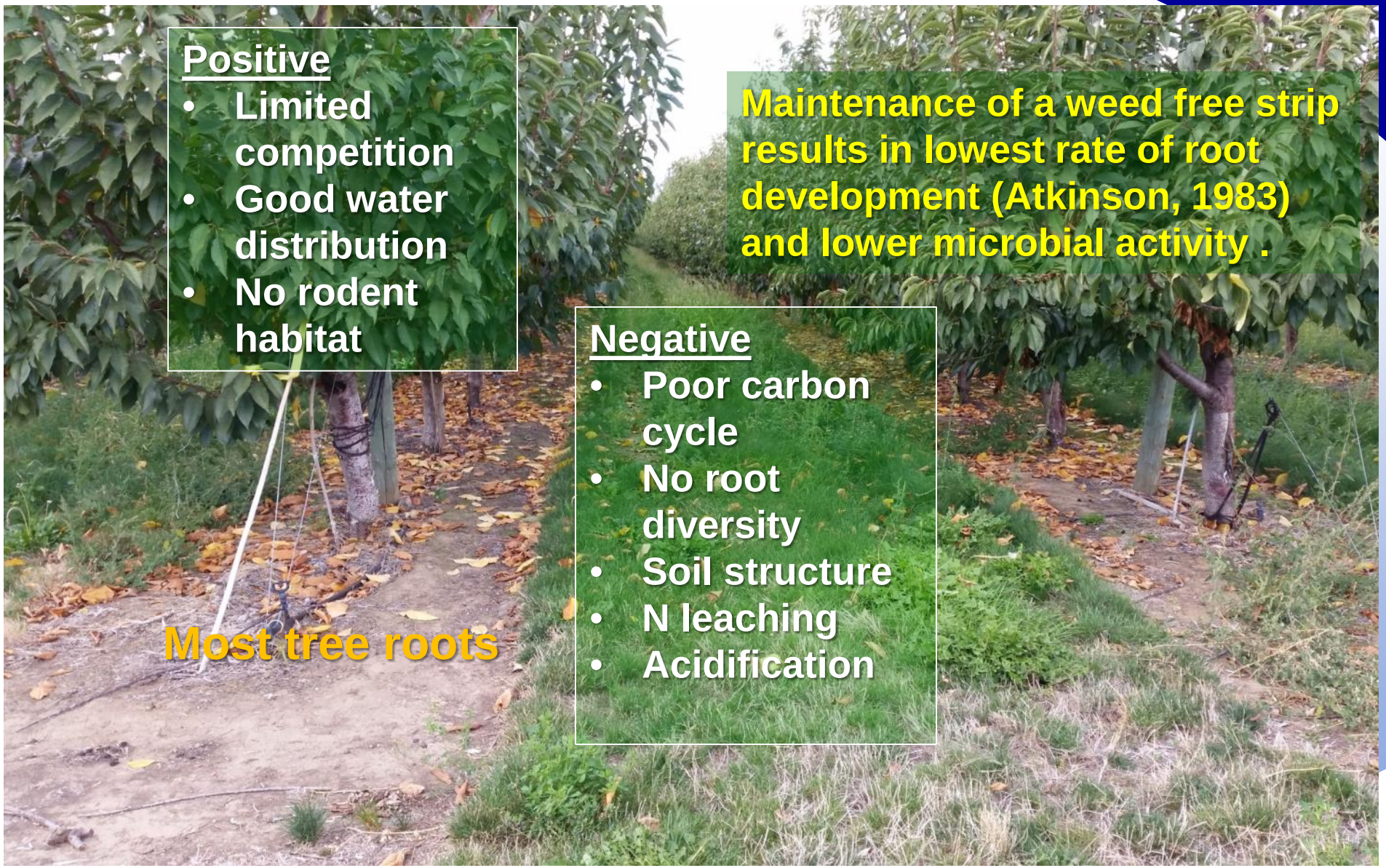
Chemical

- Gas exchange with roots
- Nutrients – retention and release
- pH – master variable

Biological

- Residue recycling; nutrient release
- Pathogens, rhizosphere – root-microbe interactions
- Nutrient, water uptake (e.g. mycorrhizae)

Modern Orchard



Positive
- Limited competition
- Good water distribution
- No rodent habitat

Maintenance of a weed free strip results in lowest rate of root development (Atkinson, 1983) and lower microbial activity .

Negative
- Poor carbon cycle
- No root diversity
- Soil structure
- N leaching
- Acidification

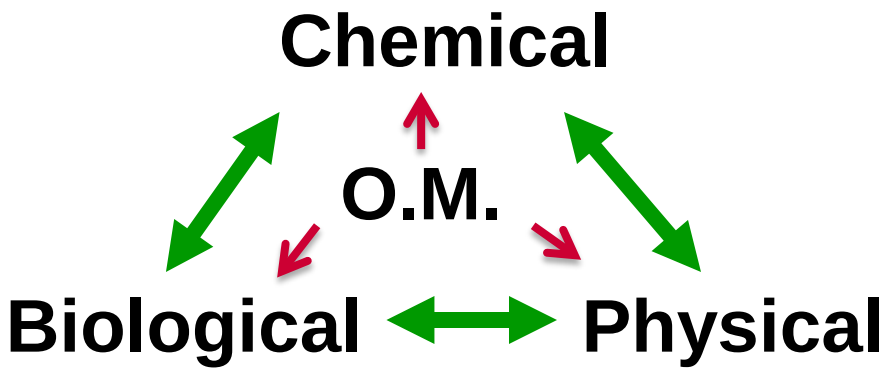
Most tree roots


(Pixabay)

Soil Quality Reference Point

Current System	Native Ecosystem	Reference Point
Dryland wheat (KS)	Prairie	Prairie
Rainfed corn (WI)	Temperate forest	Pasture ?
Paddy rice (Asia)	Tropical rainforest	??
Irrigated potatoes (ID)	Shrub-steppe	Pasture ?
Orchard (Yakima)	Shrub-steppe	??
Blueberry (Mt. Vernon)	Forest edge, bogs	??

Soil Quality



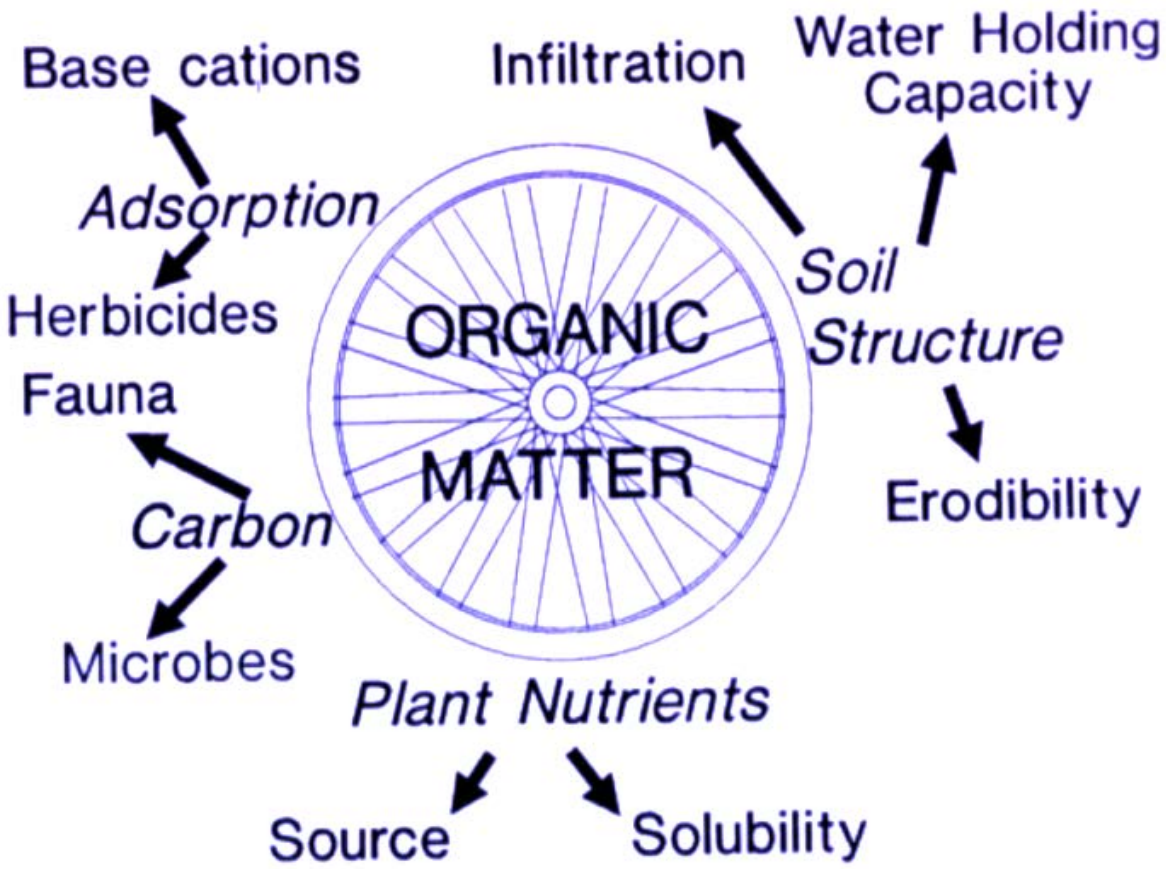
- Physical, chemical, biological properties continually interact
- Influenced by environment (climate, geology, plants)
- Influenced by human activity (erosion, fertilization, irrigation, plants)

Focus on what problem(s) you want to solve

4 Principles of Soil Quality

	Tree	Alley
• Minimize soil disturbance.	+	+
• Keep the soil covered as much as possible.	-	+
• Diversify with crop rotation and cover crops.	-	-
• Try to provide living roots in the soil for as much of the year as possible.	+	+

Soil Organic Matter
Key to Soil quality



- **Based on carbon**
- **Affects:**
  - **physical**
  - **chemical**
  - **biological**

Greatest single factor determining natural soil productivity = amount & depth of SOM

L. Carpenter-Boggs

Soil Organic Matter

Friends:

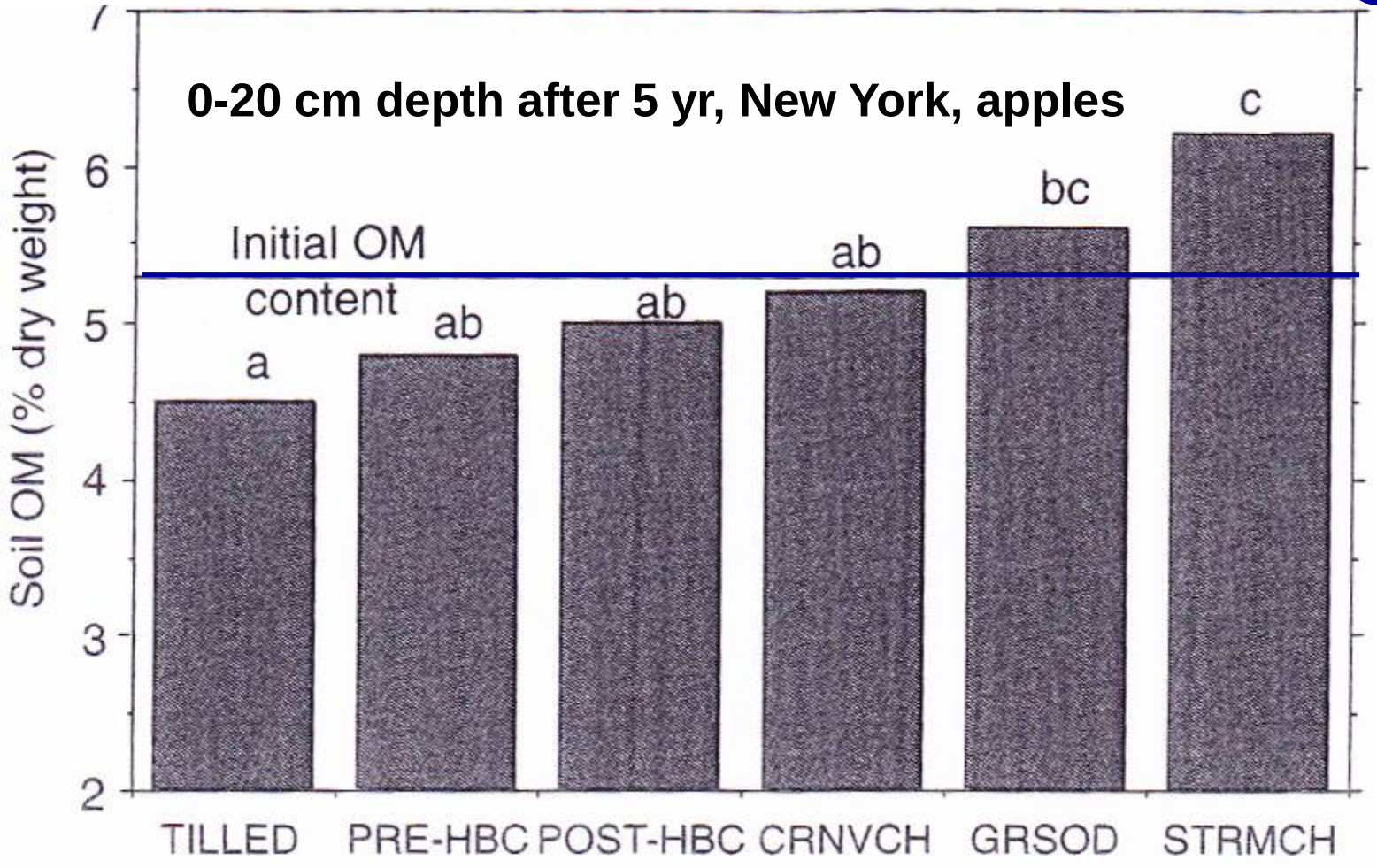
No-till
Mulching
Organic amendments
Cool temperatures
Nutrient balance

Enemies:

Tillage
Erosion
Fumigation
Herbicides, bare ground
Leaching, nutrient export

Goal: Inputs ≥ Losses

Soil Organic Matter Change

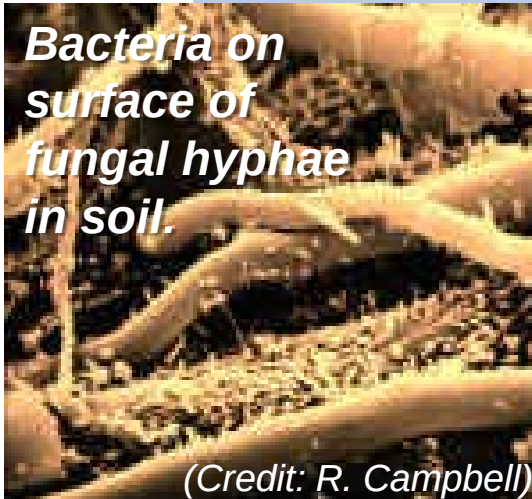


(Merwin, 2003)

Soil Biology

What Do Soil Organisms Do?

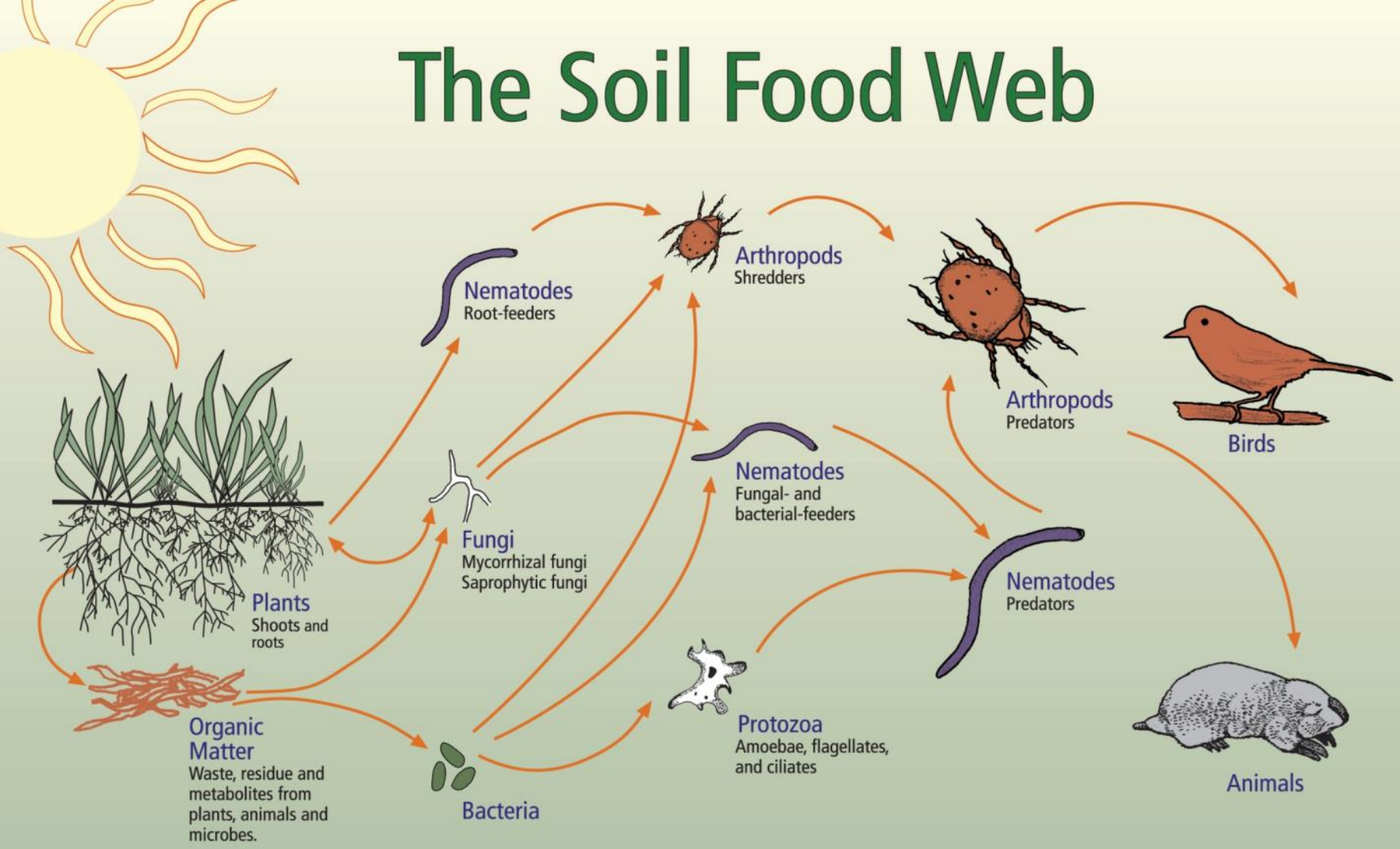
- Break down organic materials, cycle nutrients
- Fix atmospheric N
- Build stable organic matter
- Process chemicals – convert fertilizers, degrade pesticides, volatilize compounds (N, As)
- Eat plant roots; control plant pathogens
- Stimulate plant growth – mycorrhizae, nutrients, hormonal effects
- Create soil aggregates, structure



Bacteria on surface of fungal hyphae in soil.

(Credit: R. Campbell)

The Soil Food Web



First trophic level:	Second trophic level:	Third trophic level:	Fourth trophic level:	Fifth and higher trophic levels:
Photosynthesizers	Decomposers Mutualists Pathogens, Parasites Root-feeders	Shredders Predators Grazers	Higher level predators	Higher level predators

Credit:Soil Biology Primer

Measuring Soil Quality

- **Soil – physical, chemical, biological; a single number “index”**
- **Plant – bioassay; specific desired outcomes**
- **Ecosystem – watershed, energy, diversity, etc.**

- **Sensory**
- **Analytical**
- **Model**

- **Qualitative vs. Quantitative**
- **Bulk soil vs. rhizosphere ?**

Cornell Soil Health Test

12 tests:
Physical
Chemical
Biological

Crops Grown: POT — Date Sampled: 3/30/2009

	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	35	49	
	Available Water Capacity (m/m)	0.09	28	water retention
	Surface Hardness (psi)	0	98	
	Subsurface Hardness (psi)	0	100	
BIOLOGICAL	Organic Matter (%)	1.3	12	energy storage, C sequestration, water retention
	Active Carbon (ppm) [Permanganate Oxidizable]	276	11	Soil Biological Activity
	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	12.6	94	
	Root Health Rating (1-9)	4.0	63	
CHEMICAL	*pH	6.2	89	
	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	7.0	100	
	*Extractable Potassium (ppm)	190	100	
	*Minor Elements		100	
	OVERALL QUALITY SCORE (OUT OF 100):		70.4	High

Measured Soil Textural Class:==> sandy loam

SAND (%): 59.9 SILT (%): 35.2 CLAY (%): 4.9

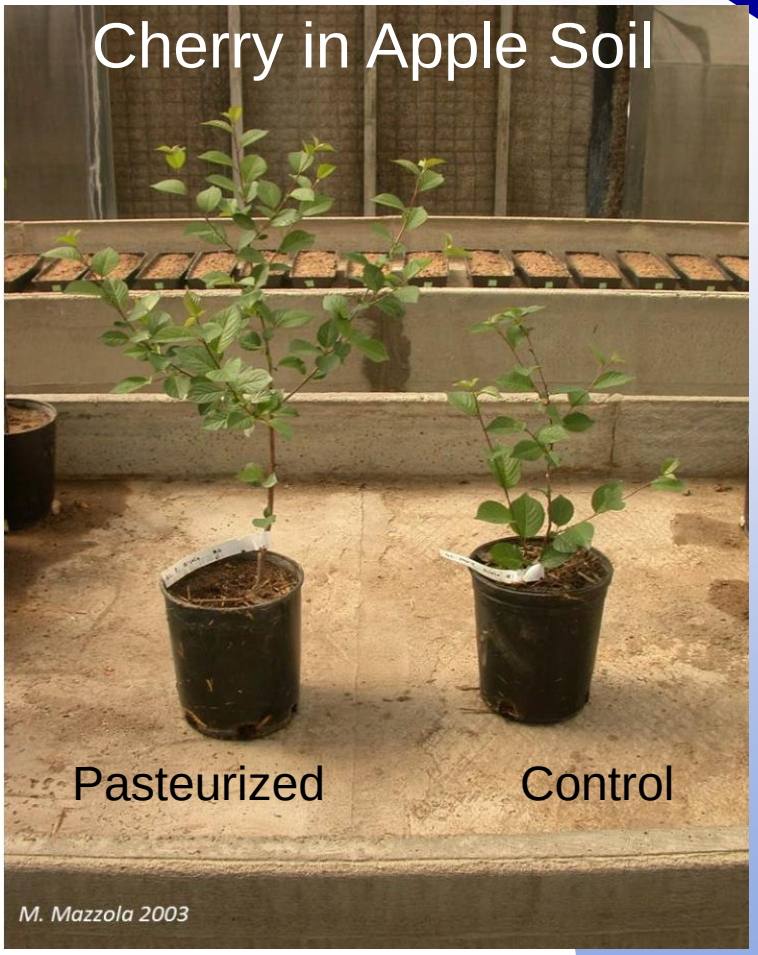
Location (GPS): Latitude=> 0 Longitude=> 0

* See Cornell Nutrient Analysis Laboratory report for recommendations

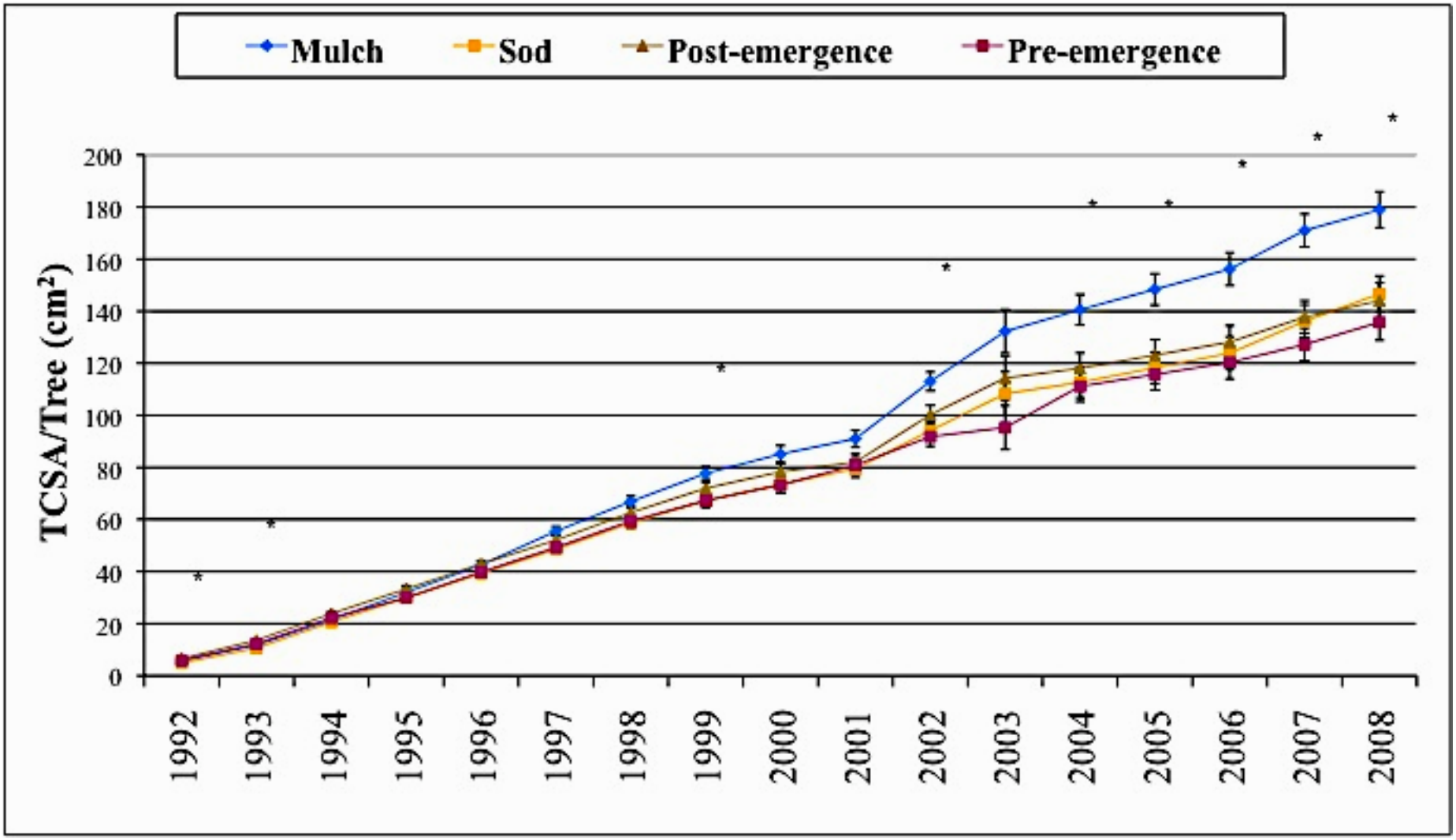
(A. McGuire)

Orchard Examples

- **Tree row management**
- **Amendments**
- **Mulches**
- **Apple replant disease**



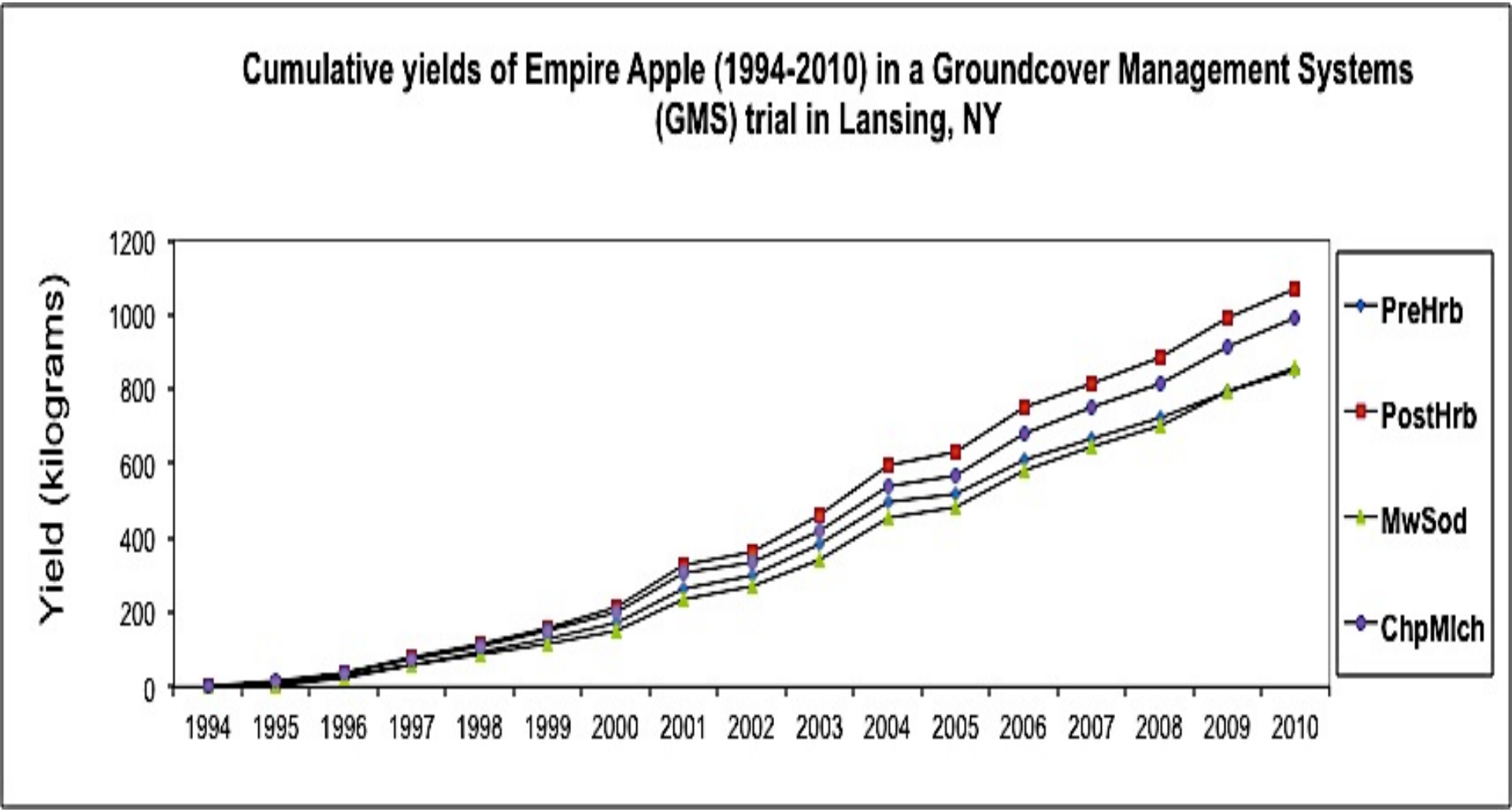
Cumulative Tree Growth in four GMSs from 1992-2008 – NY apple



TCSA=trunk cross sectional area

(Courtesy: I. Merwin)

Cumulative Fruit Yields per tree in the Four GMSs, 1994 to 2010



Standard GMS (pre+post weed free strip) was not most productive over time.

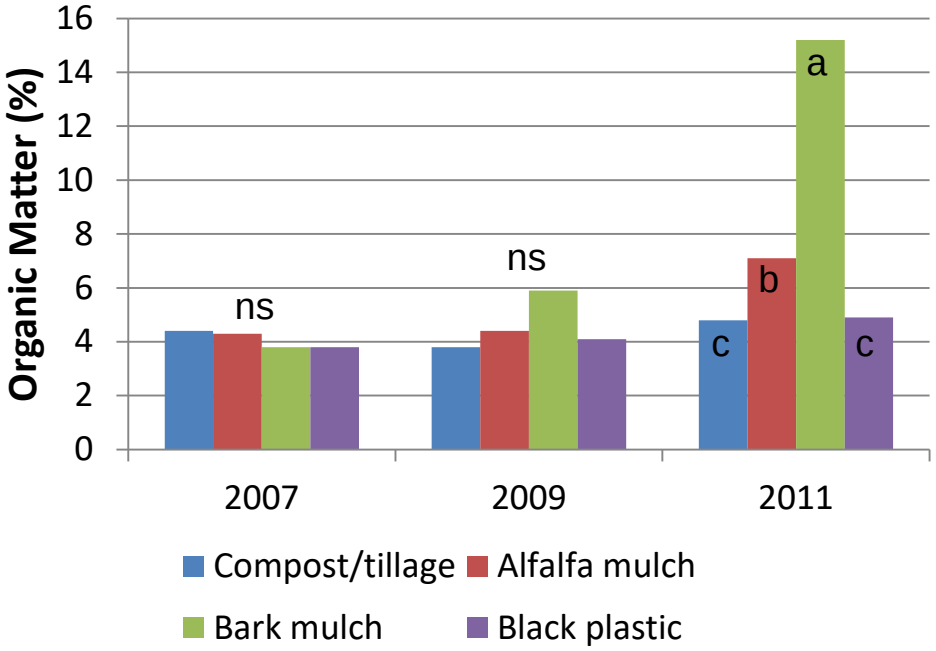
(Courtesy: I. Merwin)

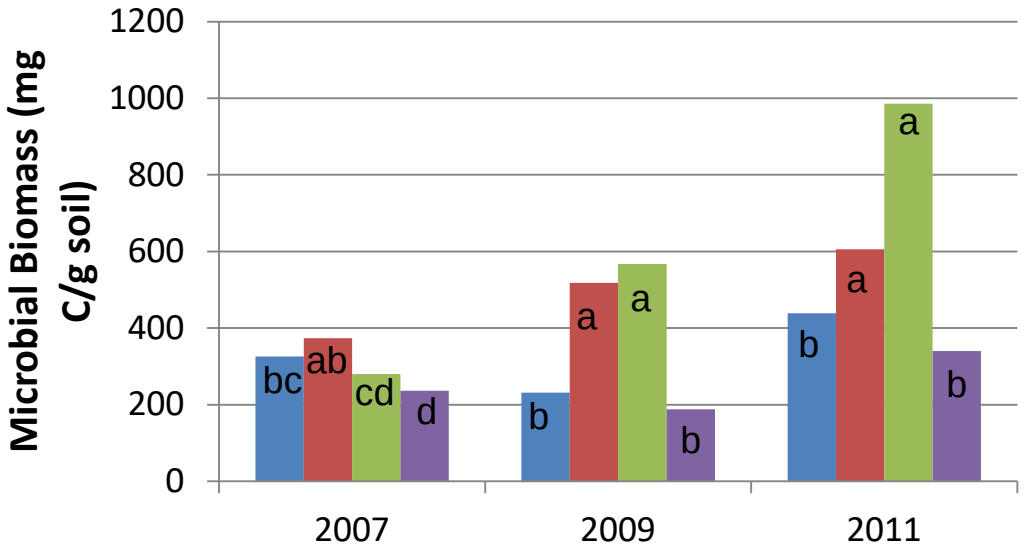
Conclusions in 2013

- **Soil health indices for orchards need more work!**
- **Bark mulch GMS optimizes soil fertility, OM, biological activity, tree growth vs. other GMSs**
- **Over time (18 years) apple trees adapt to different soil management systems**
- **Conventional weed-free residual herbicide GMS: least productive, higher nutrient leaching and runoff compared with the other systems**
- **Each GMS promotes a different microbial community in the root zone of apple trees**

(Courtesy: I. Merwin)

Organic Apple OFM Study





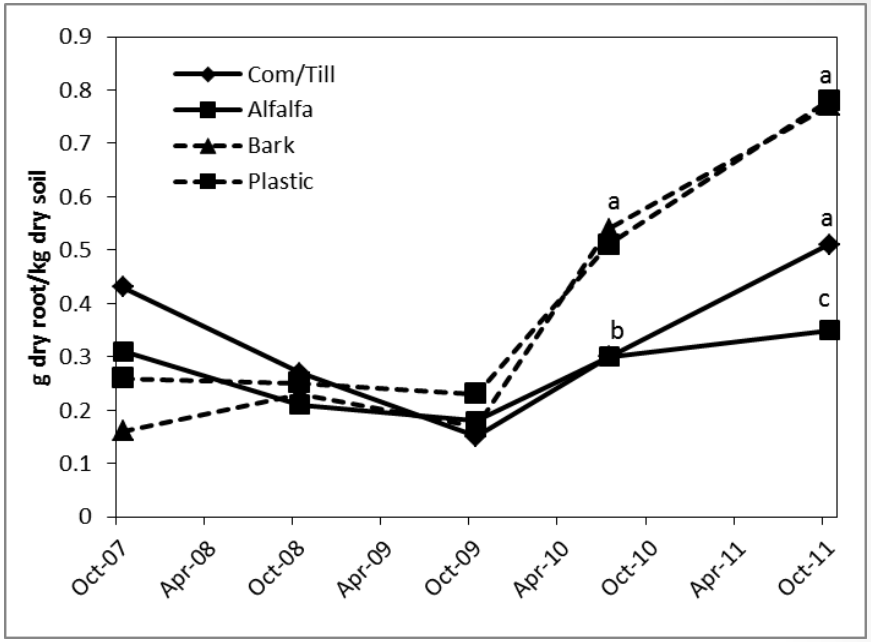
- Summerland, BC
- Planted spring 2006
- Fertile soil
- Alfalfa, bark elevated K, P cycling, more microbial biomass
- More OM with mulch

(Neilsen et al., 2014)

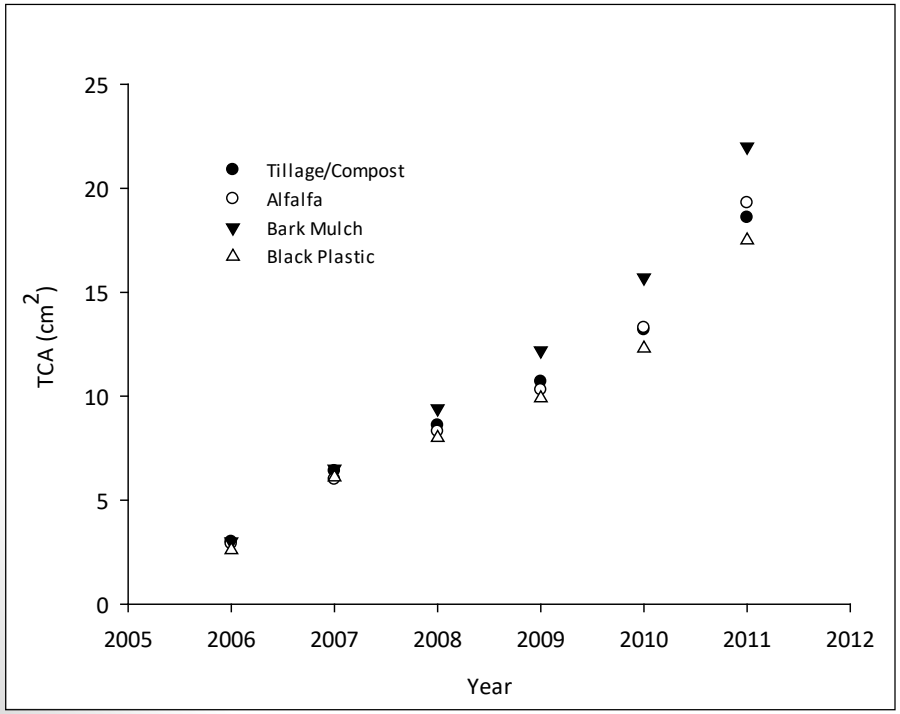
Tree Responses

- Trees grew bigger with mulch
- No significant effects on fruit yield or quality (2 yr)

Root biomass



Trunk cross-sectional area

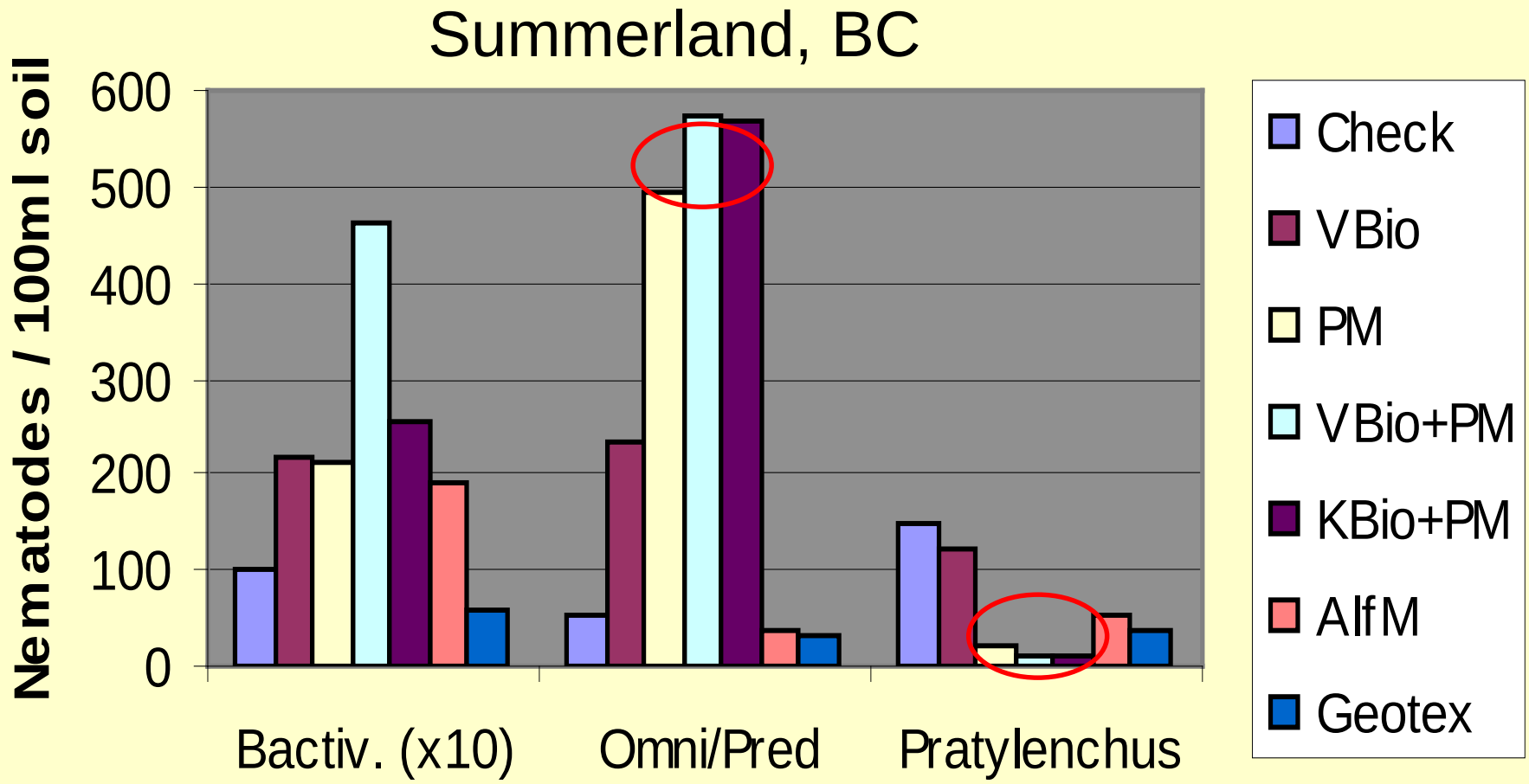


Take home message:

- Effects on soil health & tree growth develop with time
- May not translate to improved yield or quality

(T. Forge)

Effect of Mulches on Nematodes in Orchard Soil



(T. Forge)

Grower Returns

Mulch compared to tillage – 3 yr effect	$/ac
• 8+ yr ‘Gala’/M.26, sandy soil	+4,777
• Mature ‘d’Anjou’ pears, good soil	+1,432

Mulch on mature cherry, ‘Bing’/Mazzard

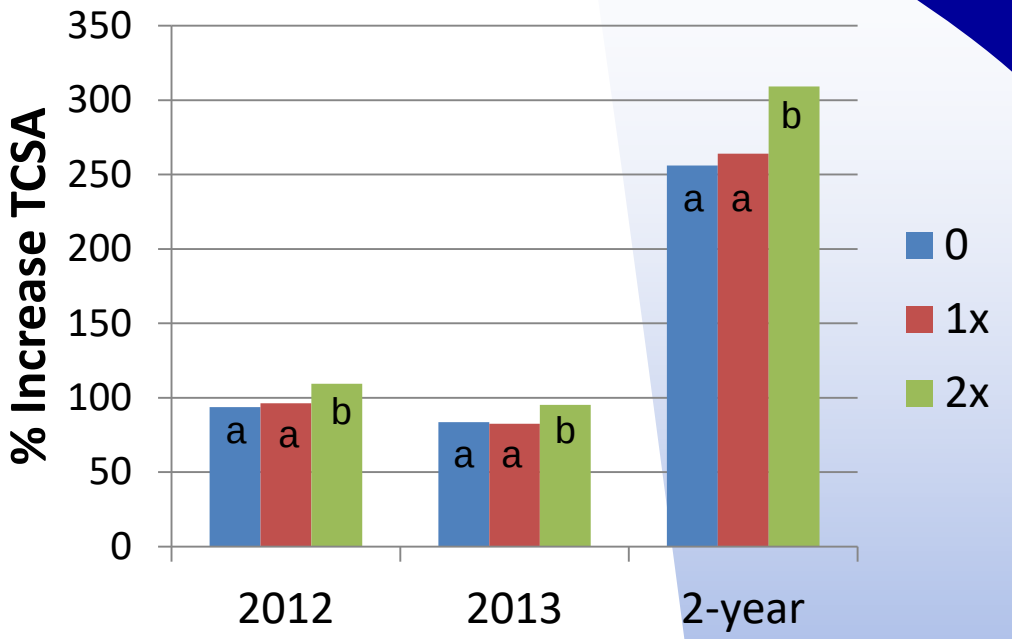
• Wood chip mulch compost blend applied October 2014; cost $1,600/ac

• Increased cherry size July 2015; benefit, $2,600/ac Net +1,000

• Internal mulch; bought large flail mower to recycle larger pruning wood that being hauled out and burned; reduced costs of hauling prunings, paid for flail in one season

‘Mow & Blow’ Mulch Trial

Quincy, WA



- ‘Fuji/M.9’ 2nd and 3rd leaf
- Tall fescue forage grass mix, mowed weekly
- 2x rate led to 20% increase in tree growth
- Clippings add 25-50 lb K/ac; 50 bin/ac apple crop removes 56 lb

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Nobili side delivery flail mower (Italy) and planted cover crop

Sweeping flailed prunings onto the tree row as an internal source of mulch.

Soil Biology and Replant Disease

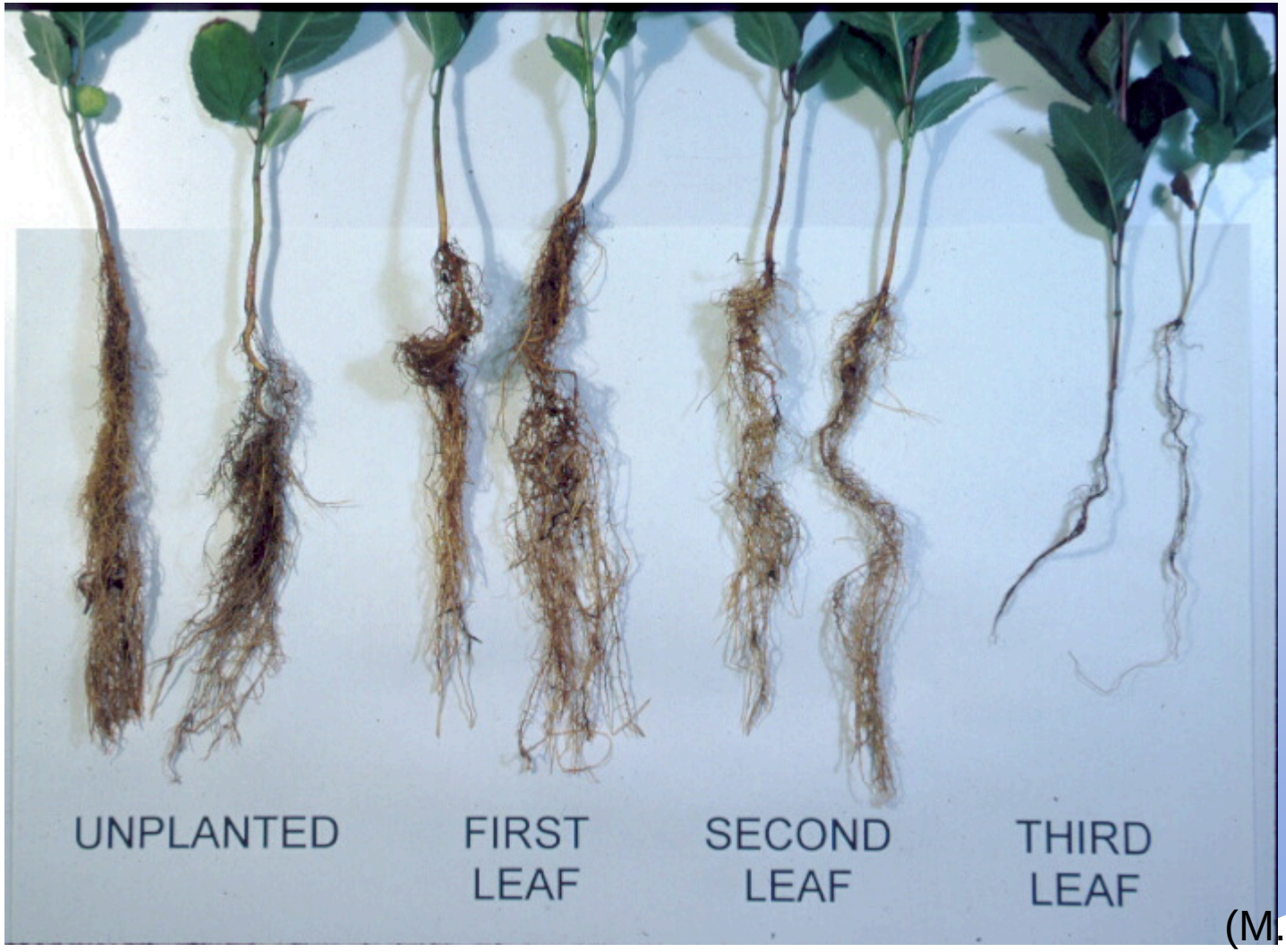
Gala/M.26, Moxee, WA

Replant soil

‘Virgin’ soil

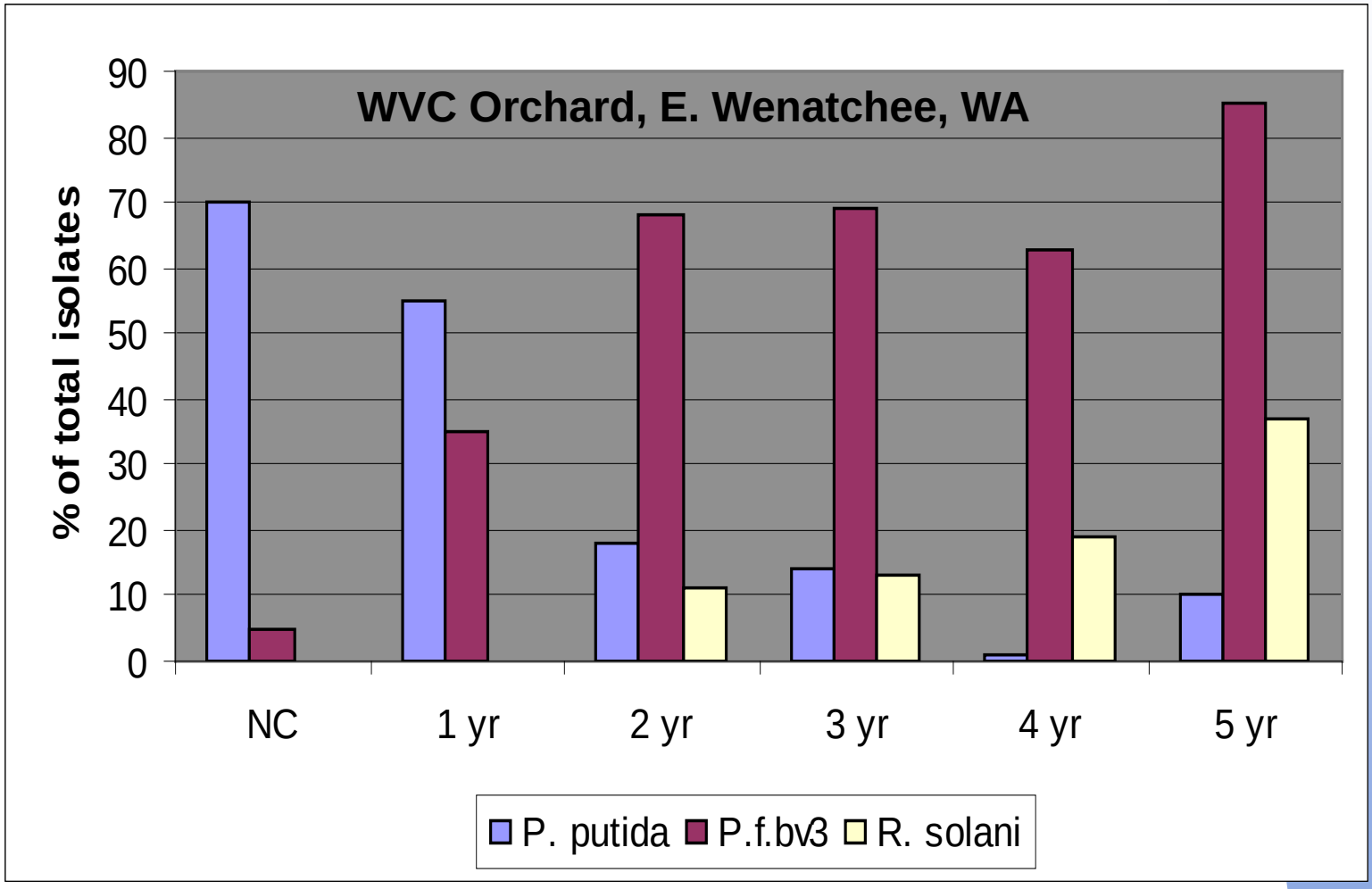
(M. Mazzola)

Growth of ‘Gala’ Apple Seedlings in Soil from Orchard Blocks of Varying Age



(M. Mazzola)

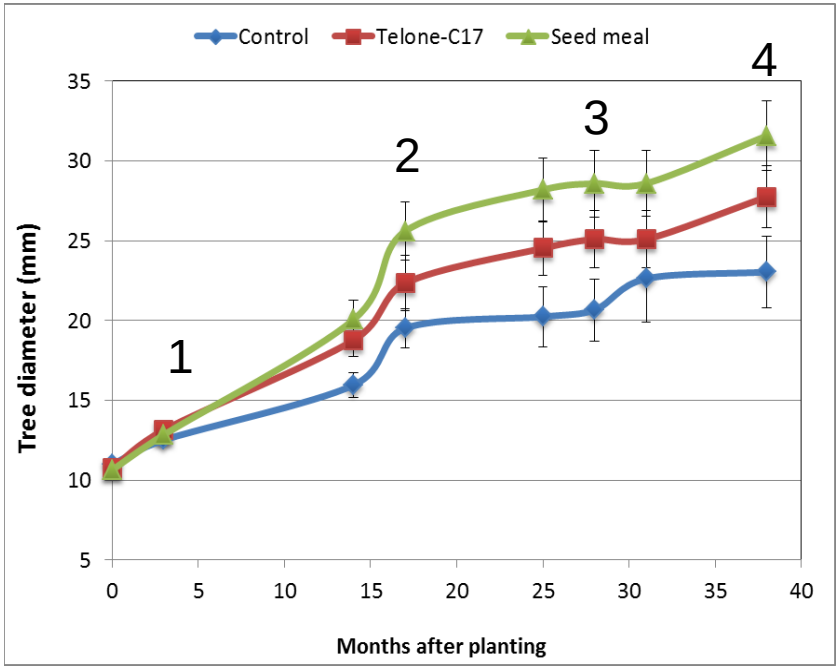
Changes in Relative Recovery of Specific Microorganisms with Increasing Age of Orchard Blocks



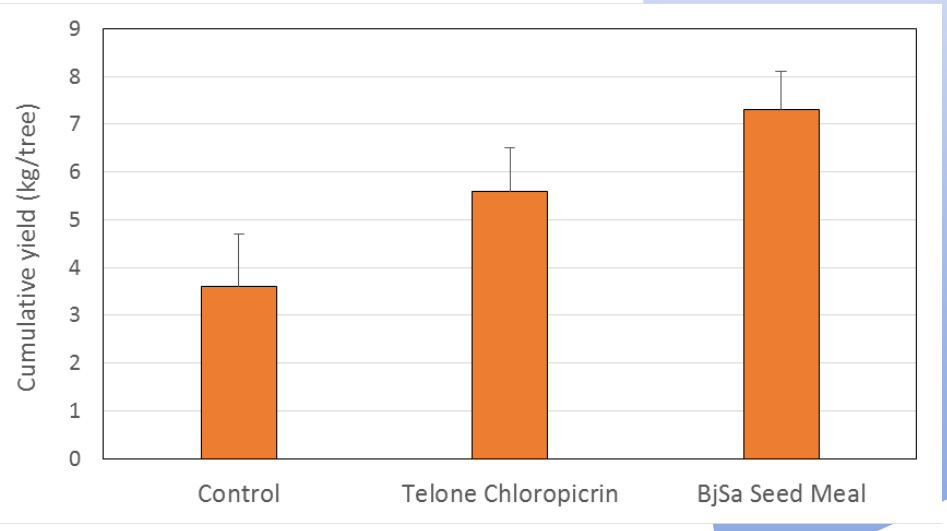
(M. Mazzola)

Soil Microbe Management for Improved Tree Growth and Yield

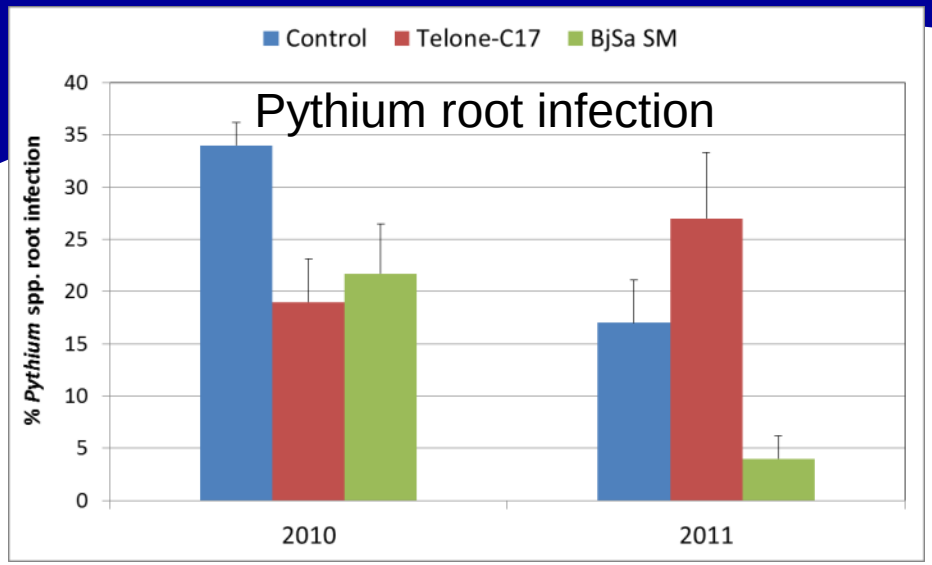
Gala/M9 increase in trunk diameter



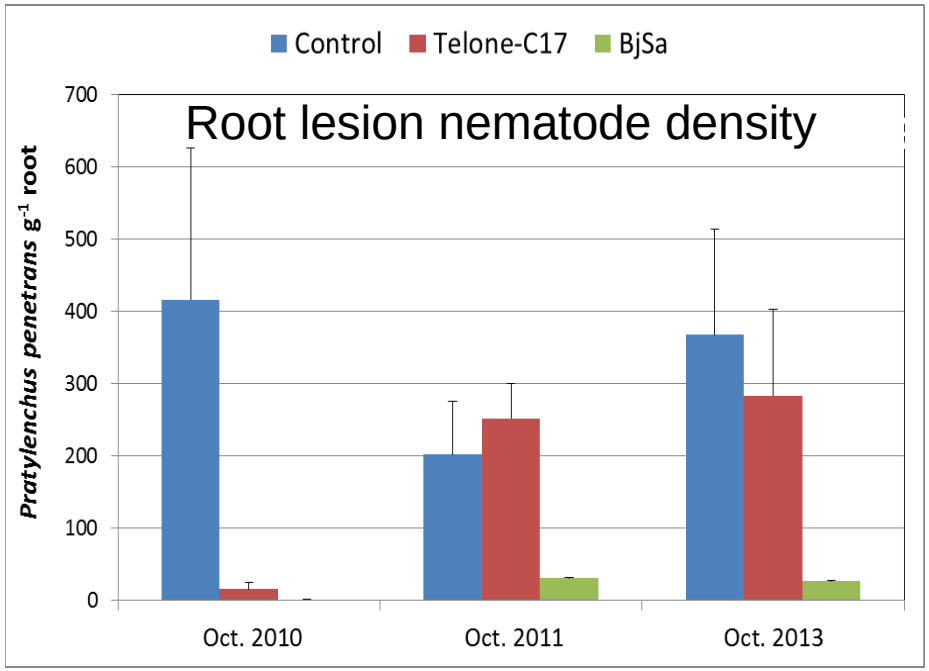
Gala/M9 cumulative yields (2012-13)

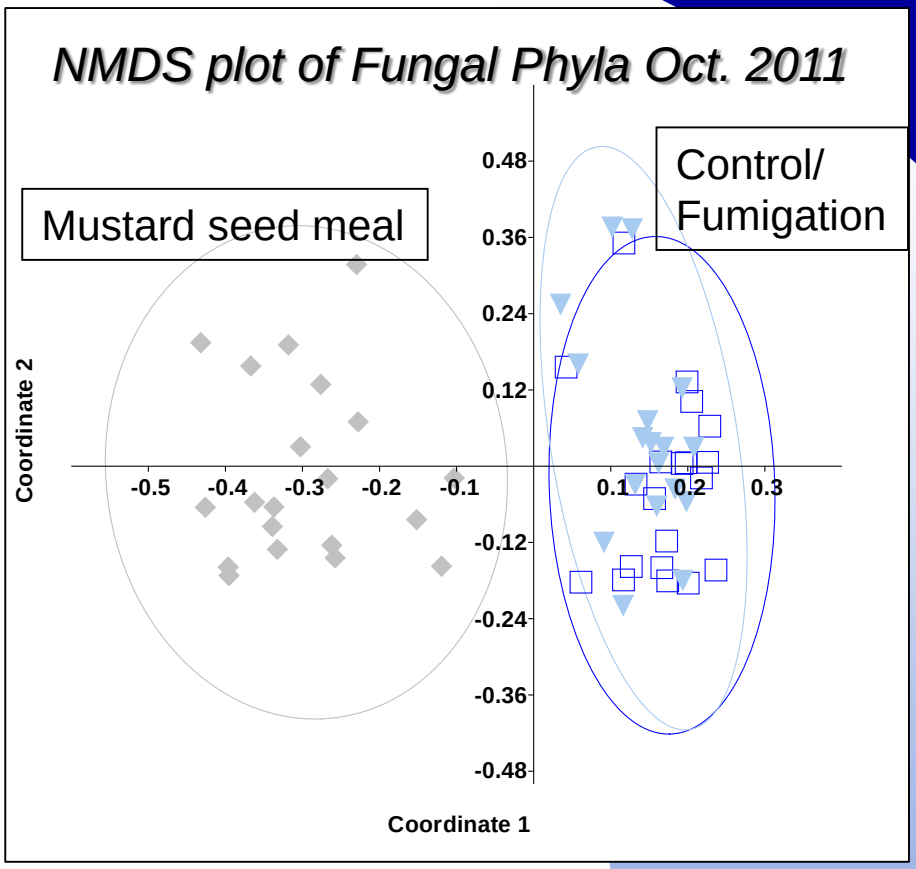


Mazzola et al. 2014.



Rhizosphere soil samples collected at end of second growing season.





"Fumigation is a one-year response in orchard systems." *G. Fazio*

Courtesy: M. Mazzola

Conclusions

- Focus on what problem you are trying to solve
- Consider physical and biological, not just chemical
- Organic matter important; surface mulch has outperformed incorporated amendment
- Soil biology has major role, poorly understood
- Soil biology can be manipulated to control replant disease

NRCS soil health web page for more info
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/

WSU orchard floor management
http://tfrec.cahnrs.wsu.edu/organicag/tree-fruit/orchard-floor-management/

WSU orchard soils
http://tfrec.cahnrs.wsu.edu/organicag/tree-fruit/soils-nutrition/

Conclusions

Soil quality / health:

- It's real
- It's hard to measure
- It's hard to predict
- It's easy to take a positive step

Do Not Disturb

Mix It Up

Keep It Covered

Tap Into Roots