Soil management impacts on orchard soil health and tree productivity

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Long-term Effects of Soil Management?

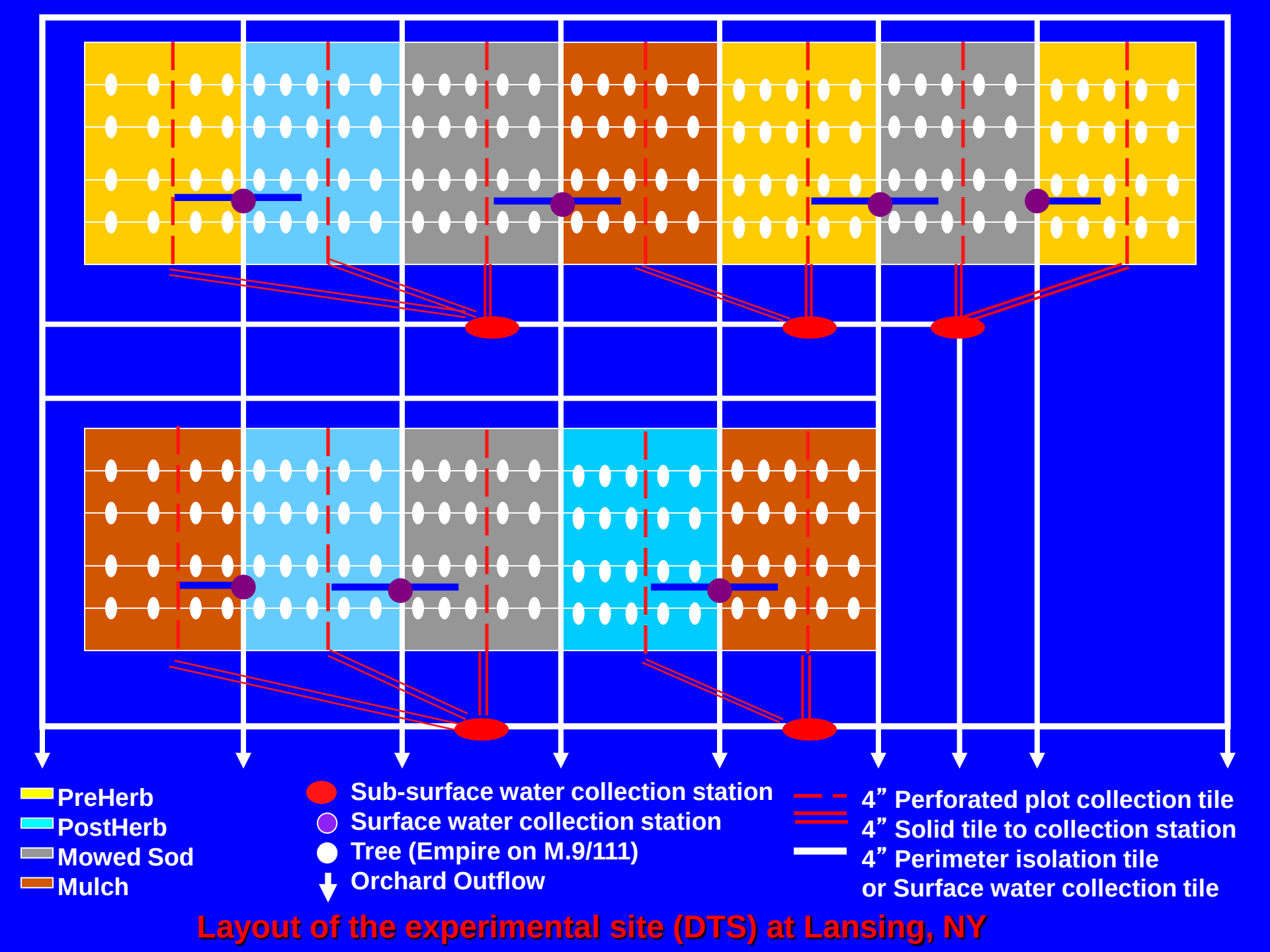
18-Year Study of four Groundcover Management Systems (GMS) in tree rows of a NY apple orchard

Treatments:

- **Mowed red fescue (*Festuca rubra*) turfgrass**
- **Hardwood Bark Mulch, renewed every 2 to 4 yrs**
- **Glyphosate in May + July each year (Post-Herb)**
- **RoundUp + Karmex + Solicam each May (Pre-Herb)**

Groundcover Management System (GMS) effects on:

- Orchard soil physical conditions?
- Tree physiology and yield?
- Agrichemical leaching and runoff?
- Nutrient availability and recycling?
- Rhizosphere microbial communities?
- Apple replant disease problems?



Layout of the experimental site (DTS) at Lansing, NY

Orchard Description

- ‘Royal Empire’ on M.9/MM.111 rootstocks
- Planted in 1992 at 3 by 6 m spacing, vertical axe
- Irrigation as needed, with micro-sprinklers
- 20-24 trees per treatment replicate (9 by 20 m plots), 3 replicates
- Soil is silty clay loam, 4% org. matter, 6-8% slope
- Under typical commercial IPM program
- Published results in Merwin et al. (1996), Atucha et al. (2011), and Yao et al. (2005 and 2007)

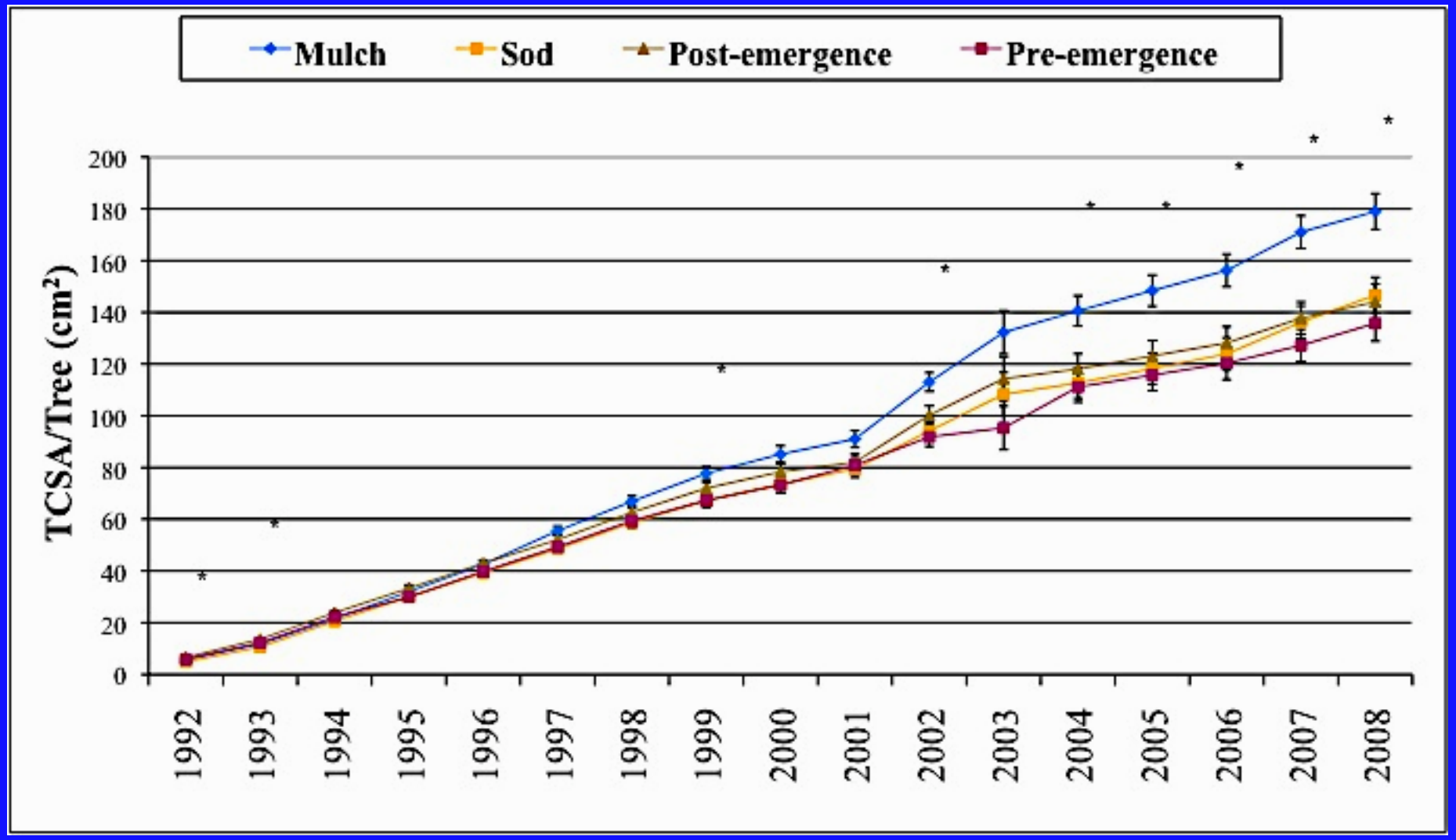
Pre-emergence herbicide

Post-emergence herbicide

Mowed Sod

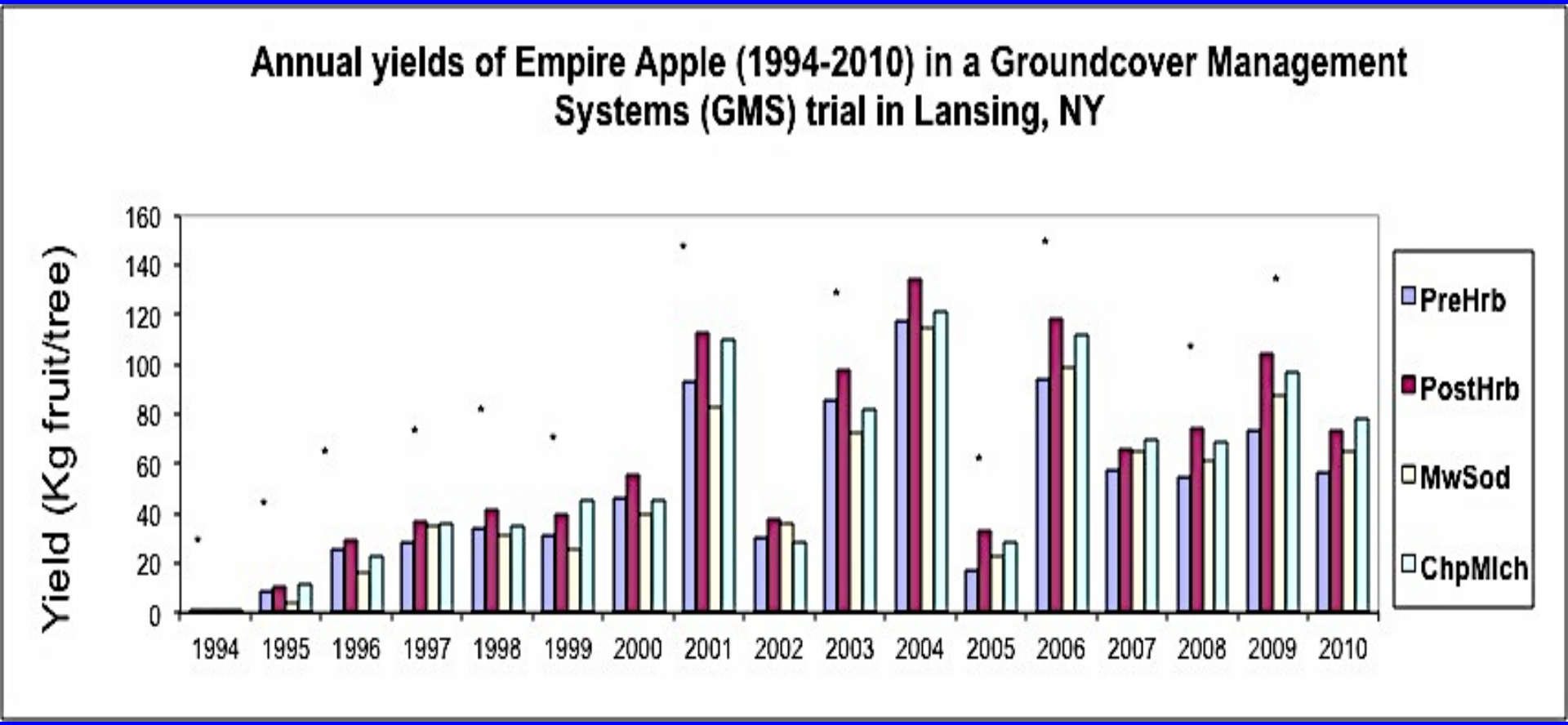
Bark Mulch

Cumulative Tree Growth in four GMSs from 1992-2009

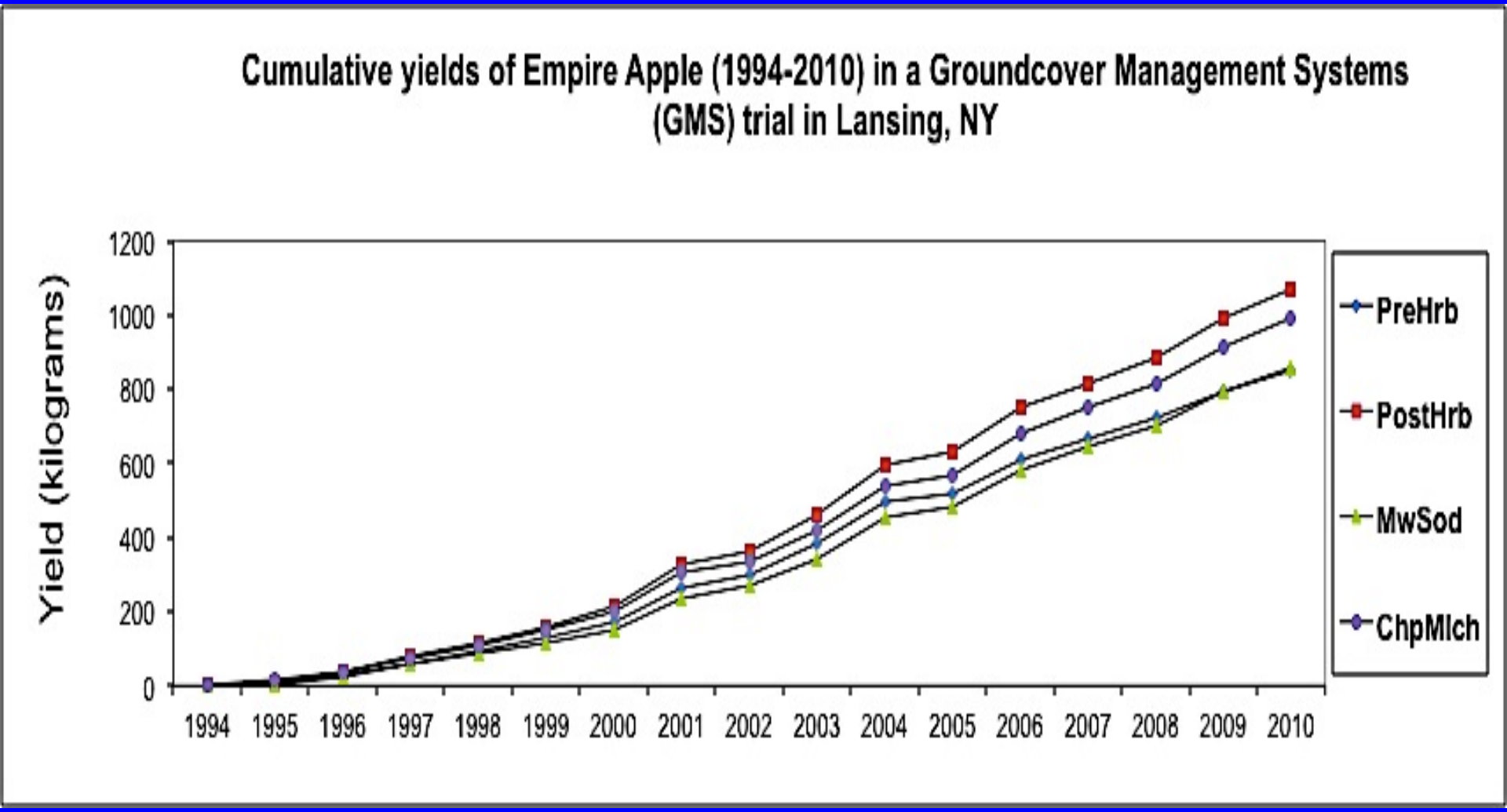


TCSA=trunk cross sectional area

Annual Yields/Tree in each GMS



Cumulative Fruit Yields per tree in the Four GMSs, 1992 to 2010



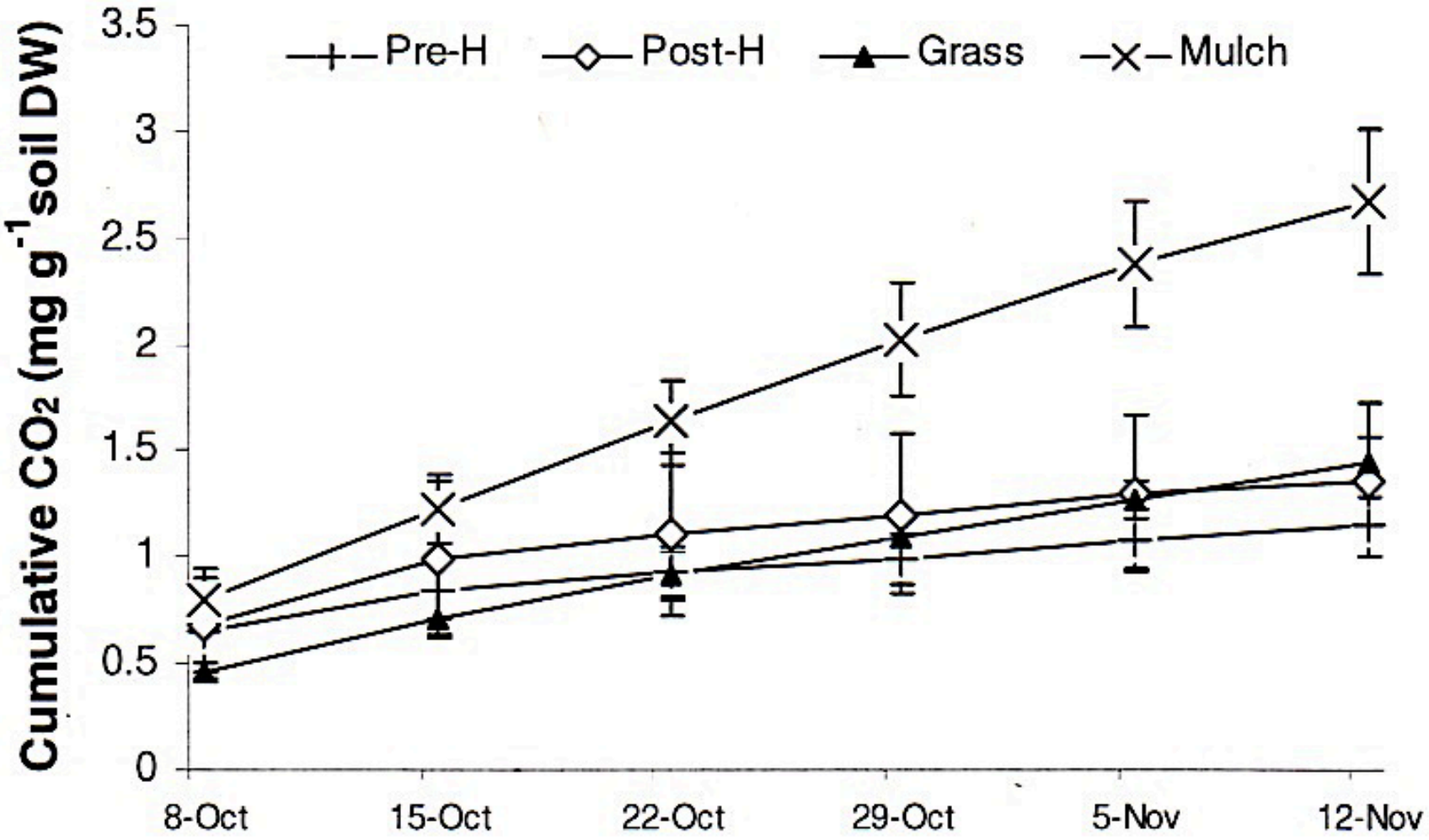
Surface cover in residual Pre-emergence (left) vs. Post-emergence (right) GMS plots, mid October

Soil fertility after 15 years under four orchard GMSs

Treatment	P (mg/kg)	K (mg/kg)	Mg (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Al (mg/kg)	Cu (mg/kg)	pH	OM (%)	CEC (cmol/kg)
Grass	0.56 b[1]	168	447	1102 b	1.5	17.0	13.1	0.30	6.5 b	5.1 b	16.8 b
Post-H	0.67 b	184	411	957 b	2.5	17.2	19.1	0.63	6.3 b	4.7 b	16.2 b
Pre-H	0.60 b	159	420	1058 b	1.5	16.8	14.7	0.70	6.4 b	4.5 b	15.3 b
Mulch	1.57 a	168	481	2630 a	1.7	24.3	8.1	0.77	7.2 a	8.6 a	22.5 a
Critical difference	0.64	36	105	438	1.8	8.7	10.7	0.58	0.4	2.0	4.6

[1] Means followed by different letters were significantly different at P=0.05.

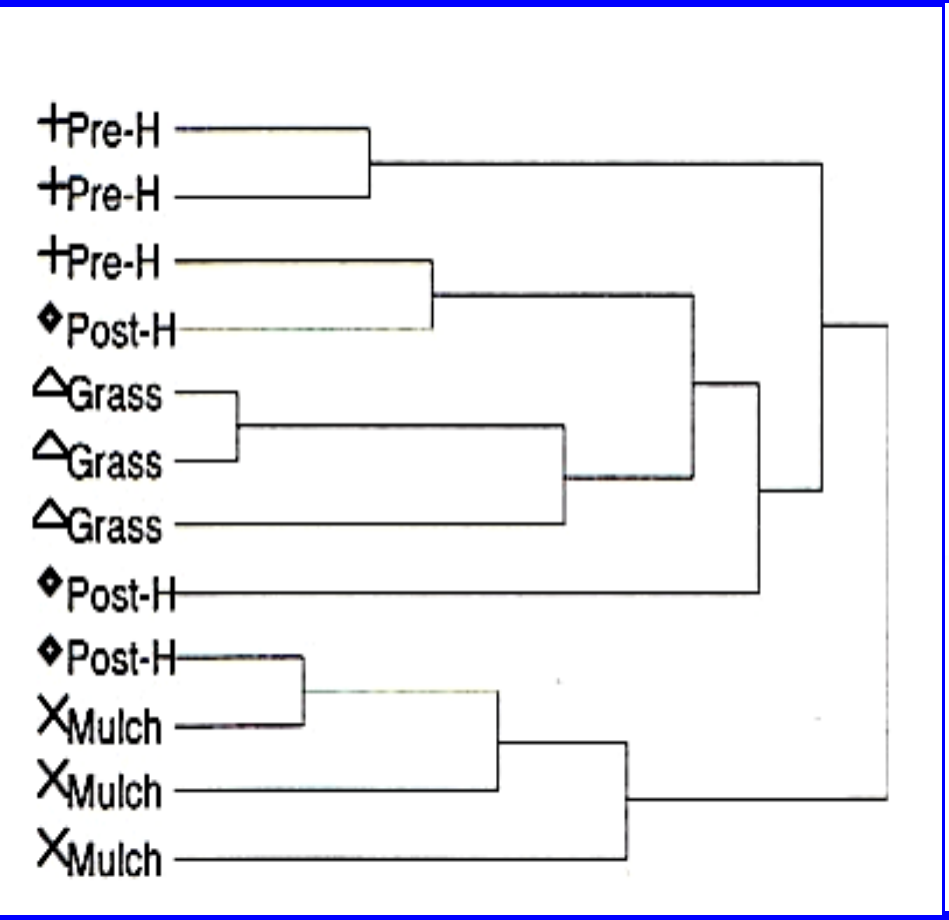
Cumulative microbial respiration in GMS soil samples (Yao et al, 2005)

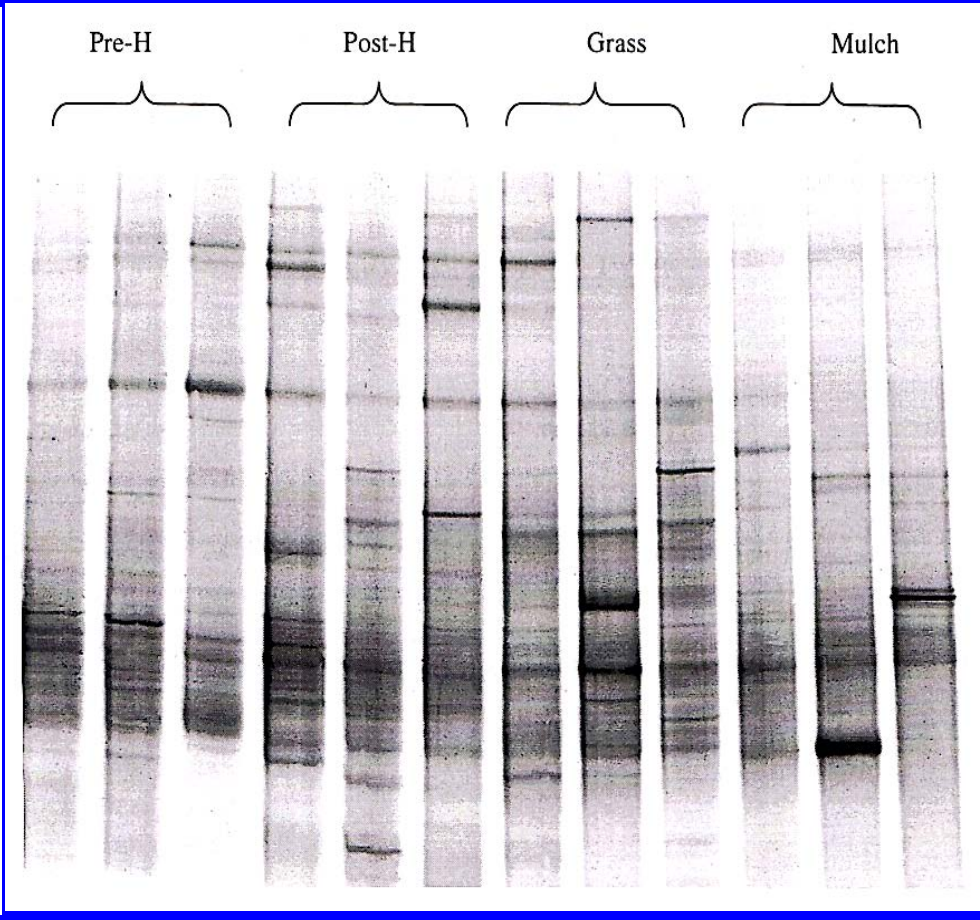


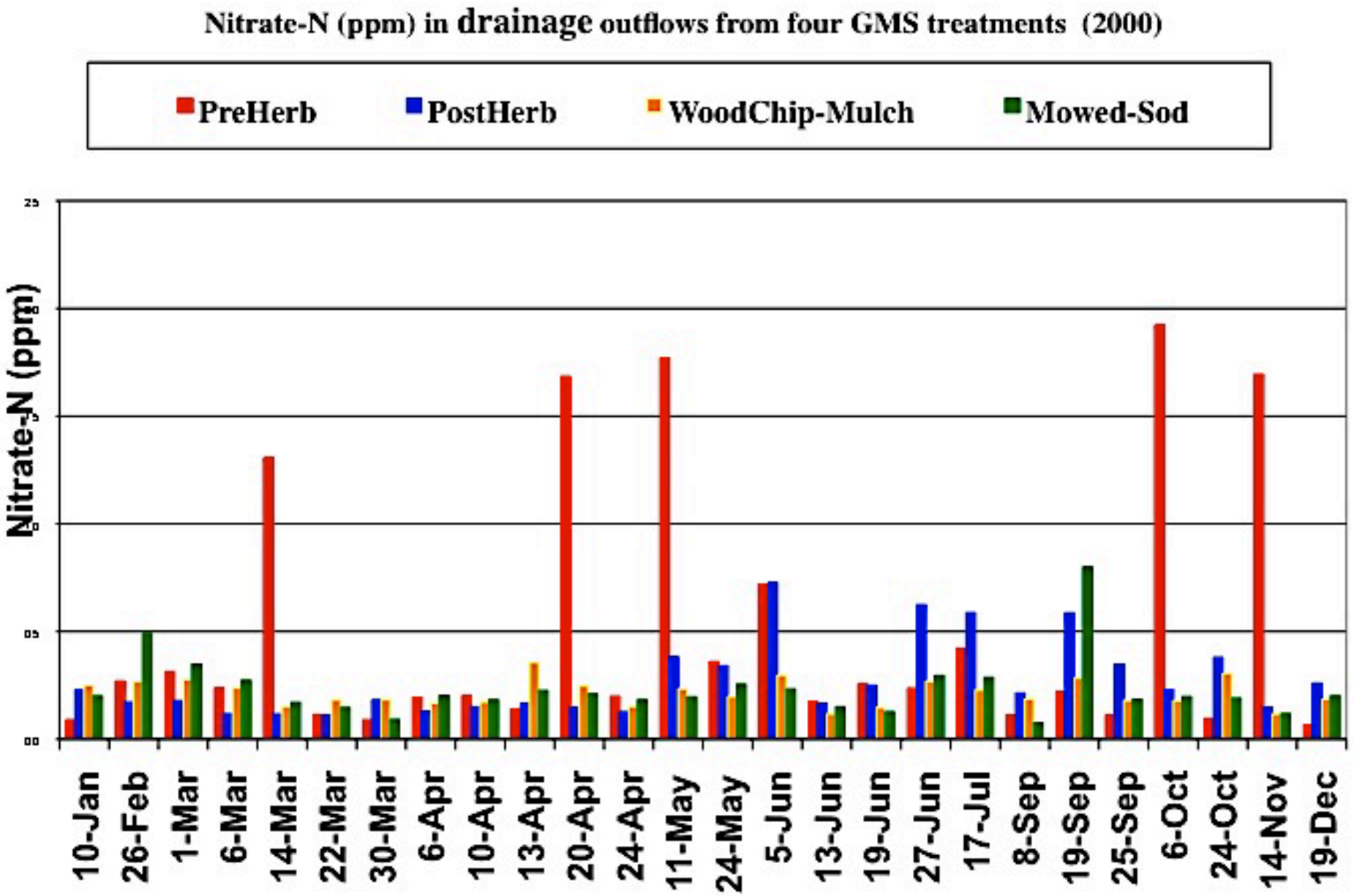
Soil microbial communities in root-zone of trees after 15 years in each GMS

- Sample topsoil within tree rows around roots
- Analyze soil nutrient availability, pH, OM, CEC
- Use selective media and culture plating to estimate populations of soil fungi and bacteria in each GMS
- Extract microbial RNA from tree row soil samples
- Amplify RNA with PCR primers targeting the 16S rRNA gene for bacteria, and the ITS (internal transcribed spacer) region for fungi
- Use Denaturing Gradient Gel Electrophoresis (DGGE) to fingerprint soil microbes in each GMS

Fungal DNA fingerprints in rootzone soil from each GMS (Yao et al, 2007)






Nitrate-N (ppm) in drainage outflows from four GMS treatments (2000)
PreHerb
PostHerb
WoodChip-Mulch
Mowed-Sod
Nitrate-N (ppm)
10-Jan
26-Feb
1-Mar
6-Mar
14-Mar
22-Mar
30-Mar
6-Apr
10-Apr
13-Apr
20-Apr
24-Apr
11-May
24-May
5-Jun
13-Jun
19-Jun
27-Jun
17-Jul
8-Sep
19-Sep
25-Sep
6-Oct
24-Oct
14-Nov
19-Dec

Nitrogen Budgets for each GMS (Atucha et al, 2011)

	Groundcover Management Systems (GMSs)							
	PreHerb (kg N $ha^{-1}yr^{-1}$)		PostHerb (kg N $ha^{-1}yr^{-1}$)		Mowed Sod (kg N $ha^{-1}yr^{-1}$)		Bark Mulch (kg N $ha^{-1}yr^{-1}$)	
	2005	2007	2005	2007	2005	2007	2005	2007
A. EXTERNAL N INPUTS								
Fertilizer application	60	0	60	0	60	0	60	0
Mulch Biomass N	0	0	0	0	0	0	169.2 †	84.6 †
Rain water	0.9	1.2	0.9	1.2	0.9	1.2	0.9	1.2
Irrigation Water	1.8	0.03	1.8	0.03	1.8	0.03	1.8	0.03
Total Inputs	62.7	1.2	62.7	1.2	62.7	1.2	62.7 (231.9)†	1.2 (85.3)†
B. INTERNAL N FLUXES								
Recycling surface vegetation	15.1	19.5	20.9	21.5	23.6	27.3	25.1	24.4
Soil N mineralization	16.7	18.4	20	20.9	22.1	24.2	29.8	31.9
Leaf litter Fall	16.4	10.7	11.6	14.2	10.3	15.4	10.3	15.9
Pruned wood	4.1	11.5	5.6	13.2	4.8	14.1	5.2	14.9
Total internal fluxes	52.3	60.1	58.1	69.8	60.8	81.0	70.4	87.1
C. N OUTPUTS								
Harvested fruit	27.7	22.9	32.9	28.1	22.0	24.8	32.4	31.2
Surface runoff	1.7	5.0	1.3	7.7	0.6	4.9	0.5	4.1
Subsurface leaching	12.2	2.6	13.9	2.6	12.2	3.2	15.9	3.7
Total outputs	41.6	30.5	48.1	38.4	34.8	32.9	48.8	39
BALANCE= (A+B)-C	73.4	30.8	72.7	32.6	88.7	49.3	84.3 (261)†	49.3 (134)†

Apple Replant Disease:

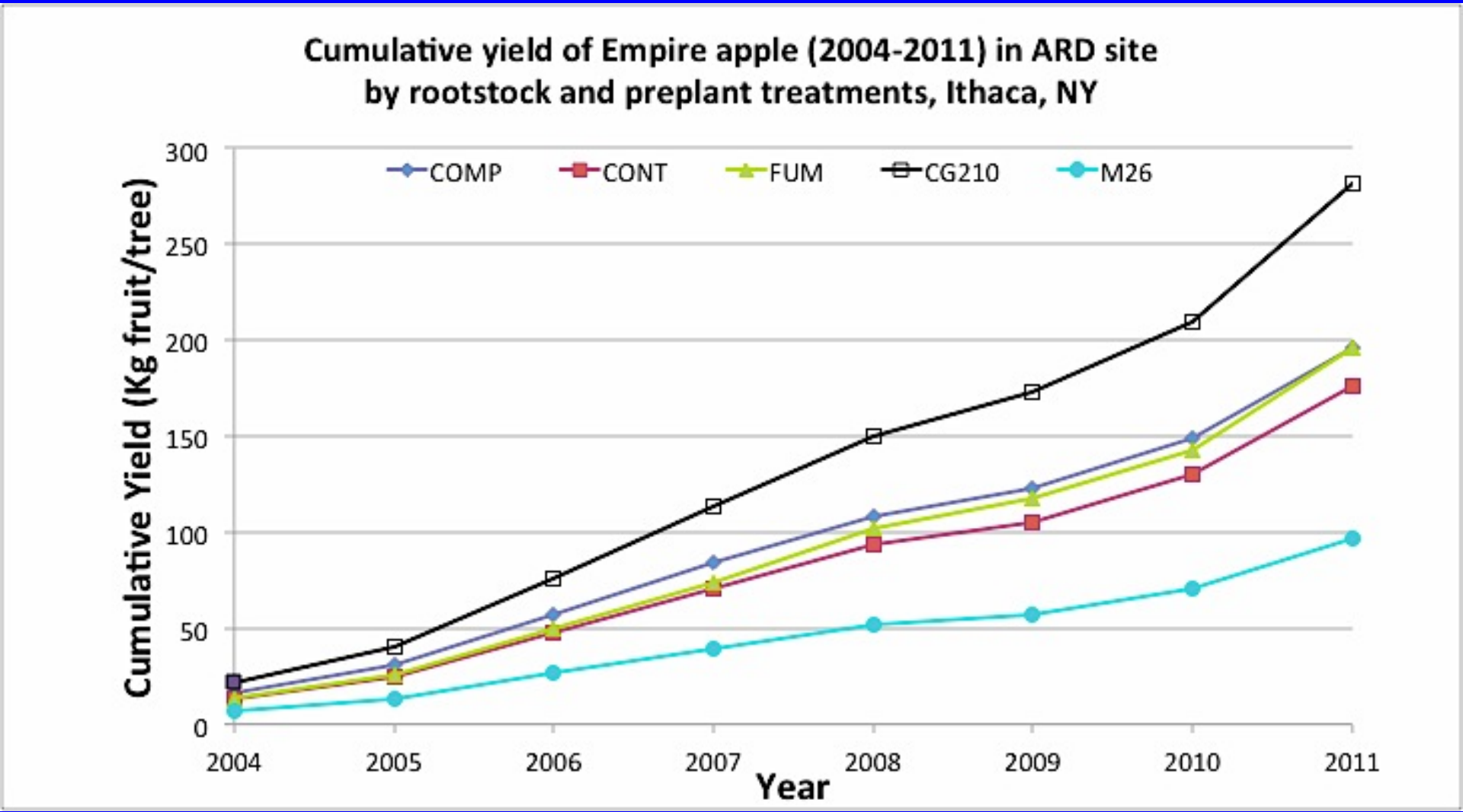
A “soil health” problem usually controlled by preplant fumigation

Ithaca ARD project (2001-2010):
Compost, rootstock type, soil fumigation and replant tree location in or out of old tree rows
(work of Drs. Leinfelder, Yao, St. Laurant)

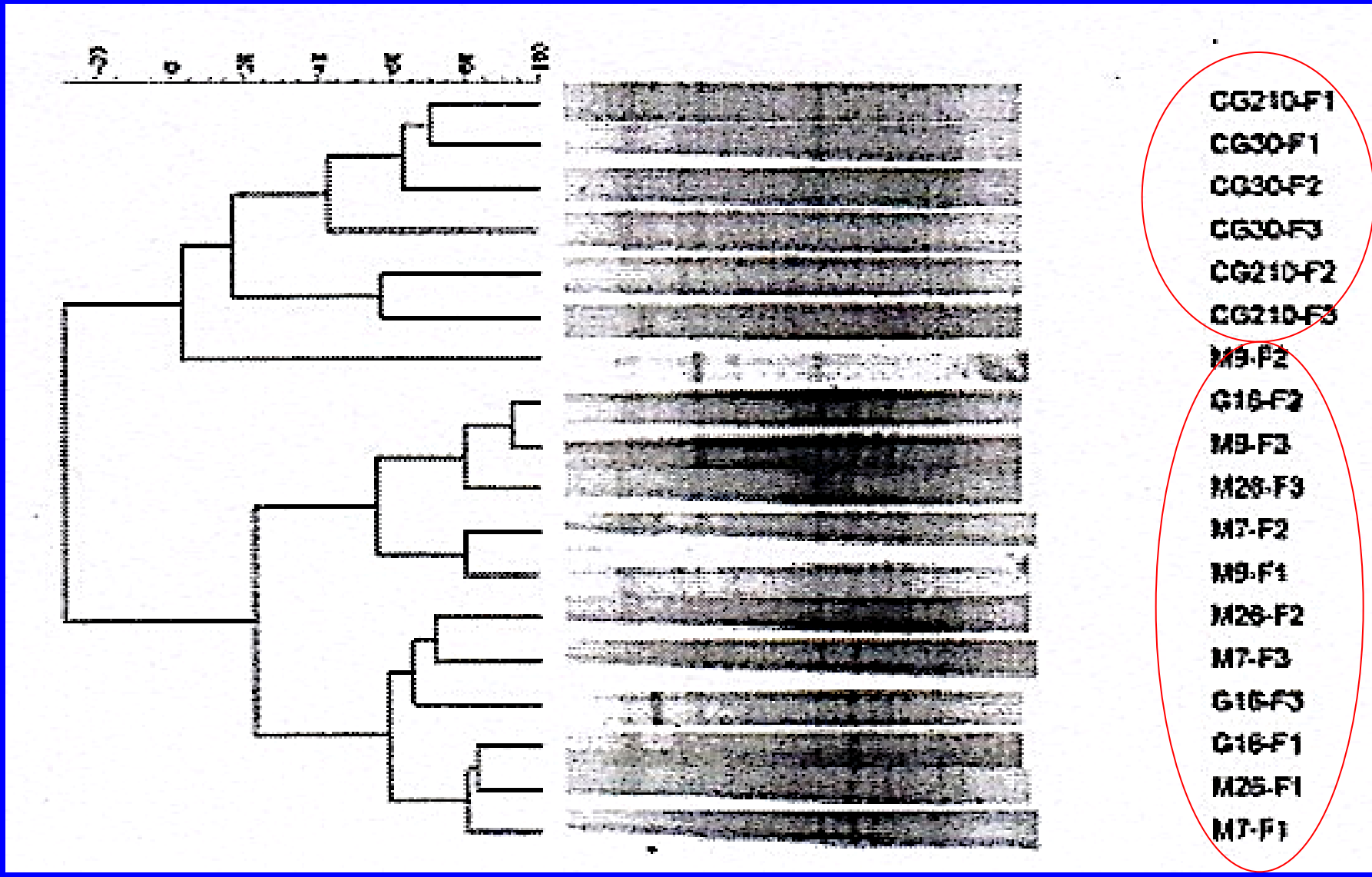
Old Tree Row vs. Old Grass Lane replant tree locations

Four years later…

Effects of preplant soil fumigation, compost, and rootstocks in replant disease orchard



Fungal DNA fingerprints of root-zone soil on Cornell-Geneva vs. Malling rootstocks



The Cornell Soil Health Index as predictor of orchard productivity? (Michelle Leinfelder's PhD)

- Orchard soil health indicators correlated well with long-term tree growth, but not yields.
- Environmental aspects of orchard soil health may be more important than its effects on fruit trees (nutrient leaching, erosion, pesticide residues, etc)
- Well managed orchards can sequester substantial amounts of carbon over time, in trees and soil

CONCLUSIONS

- 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, yields become similar
- 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
- Geneva rootstocks more tolerant of replant disease, which is a soil health related problem