How Will Orchard Soil Health Impact China's Apple Growers?

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What is Orchard Soil Health?

- Soils ability to sustain long-term tree health, fruit production, and profitability
- Soil environmental functions—Nutrient retention and availability, water storage and quality, carbon storage
- Build-up of orchard root pathogens—Replant Disease
- Physical conditions of soil—Wind and water erosion, soil aggregate stability, soil organic matter, aeration

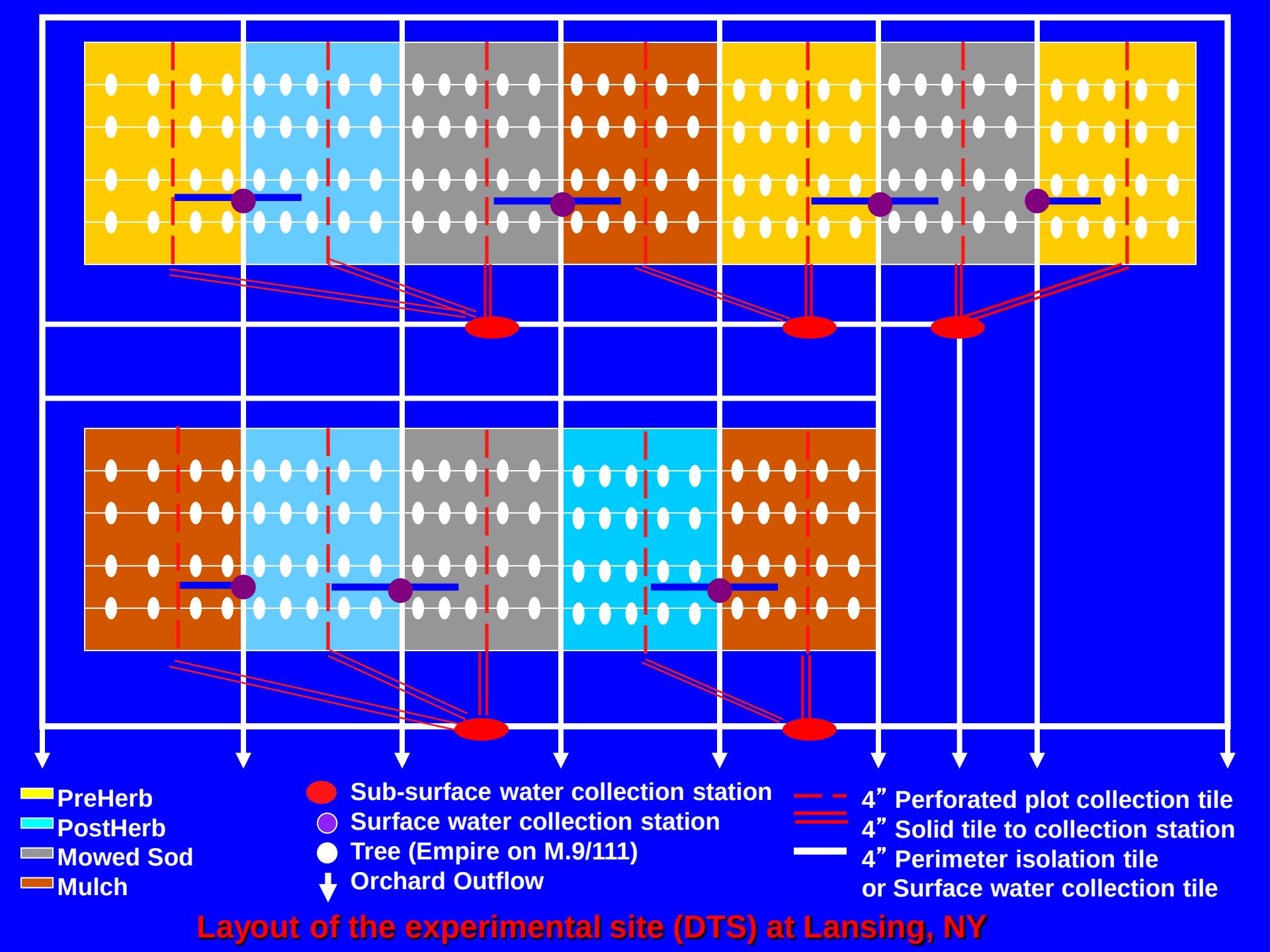
Groundcover Management Effects on Soil Health?

An 18-Year Test of Four Groundcover Management Systems (GMSs) in a New York Orchard

- Mowed red fescue (*Festuca rubra*) turfgrass
- Composted Bark Mulch, renewed every 2 to 4 yrs
- Glyphosate in May + July each year (Post-Herb)
  (weed regrowth each year during the dormant season)
- Glyphosate + Diuron + Norflurazon (Pre-Herb)
  (maintains weed-free bare-soil conditions year round)

Soil Management Effects On:

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



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

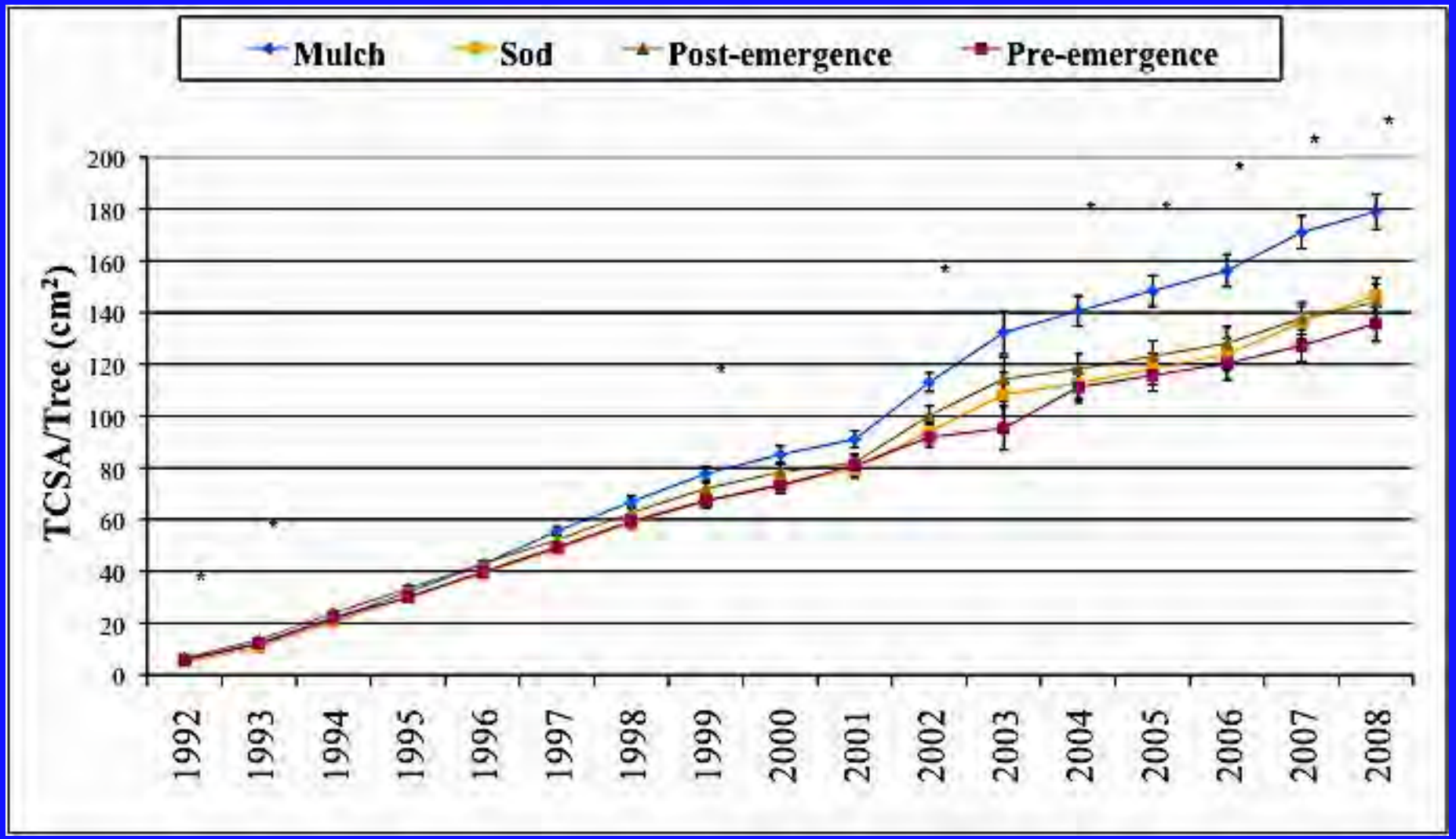
Pre-emergence herbicides

Post-emergence herbicide

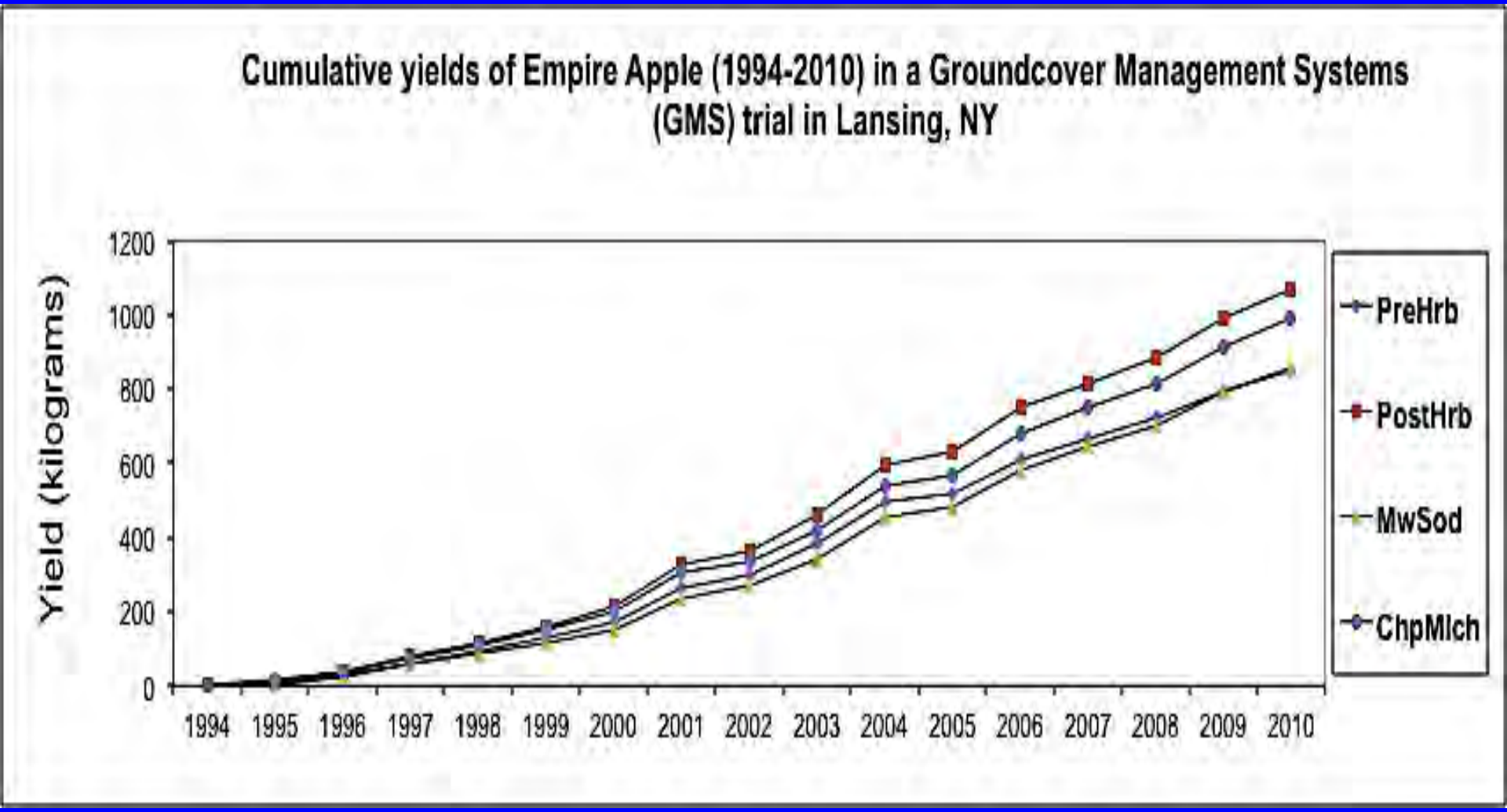
Mowed Sod

Bark Mulch

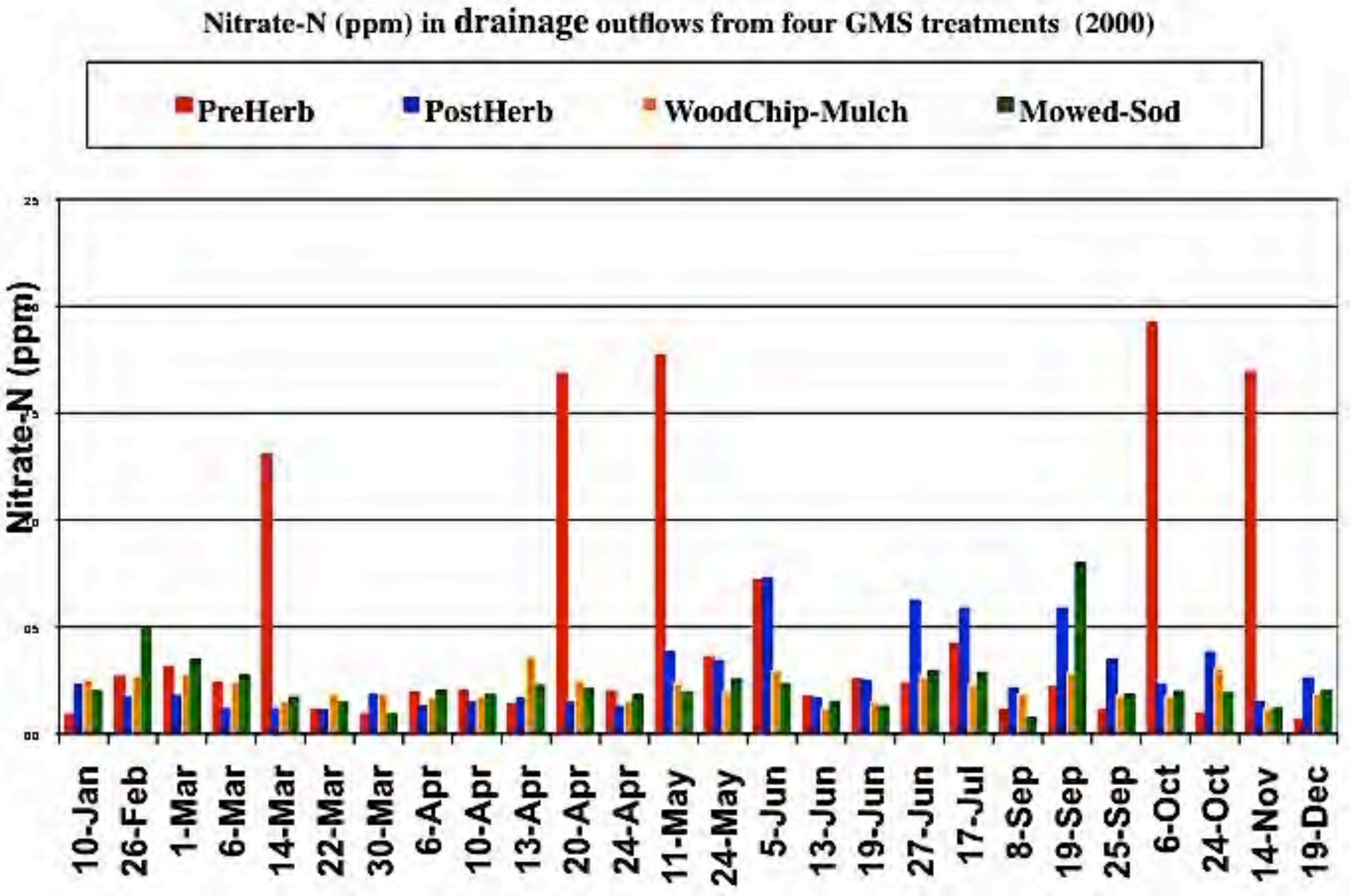
Cumulative Tree Growth in four GMSs from 1992-2009



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

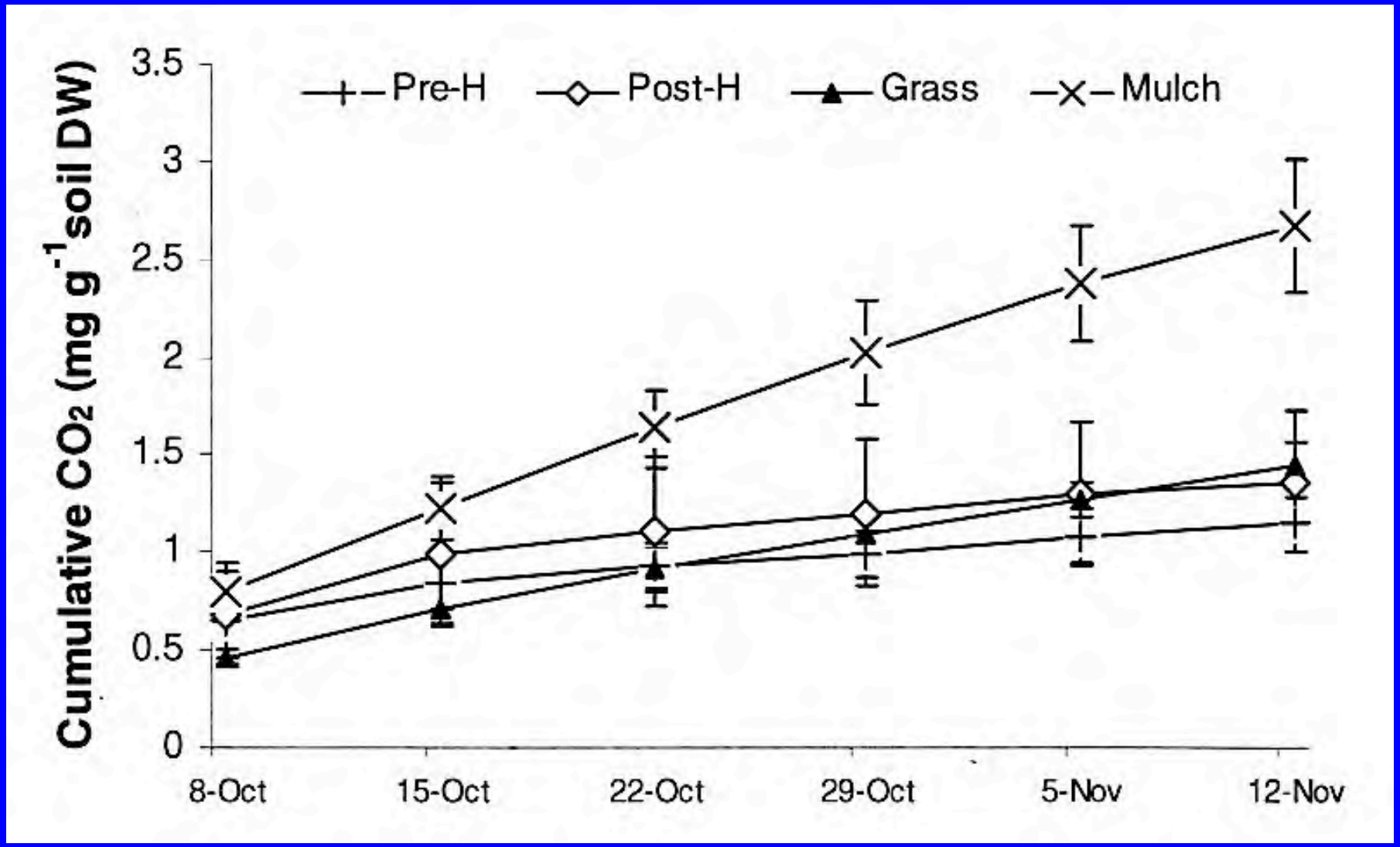


Surface cover in residual Pre-emergence (left) vs. Post-emergence (right) GMS plots, mid October


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

The 3 muddy runoff water samples below all came from tree-row plots of the residual pre-emergence herbicide treatment. Lack of groundcover in this GMS treatment increased soil erosion, and eventually reduced tree growth and fruit yields…

Microbial respiration (biological activity) in GMS samples after 13 yrs (Yao et al, 2005)

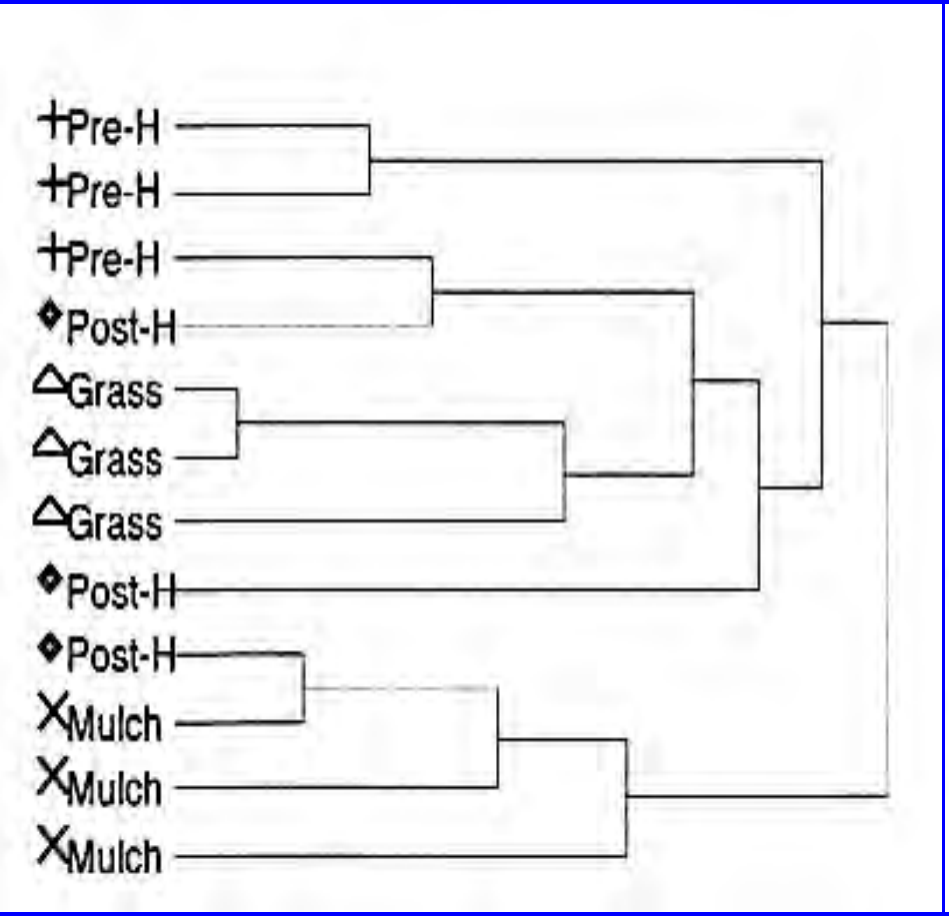


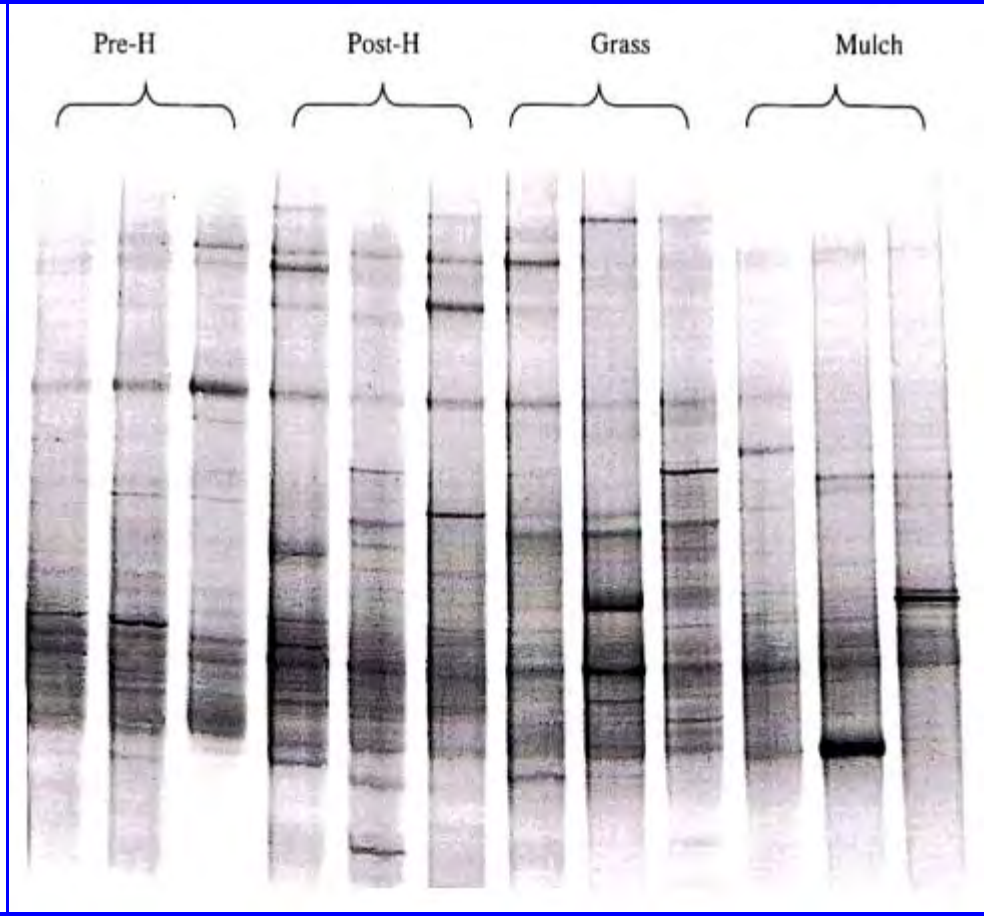
Soil fertility after 15 years under four orchard GMSs

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.

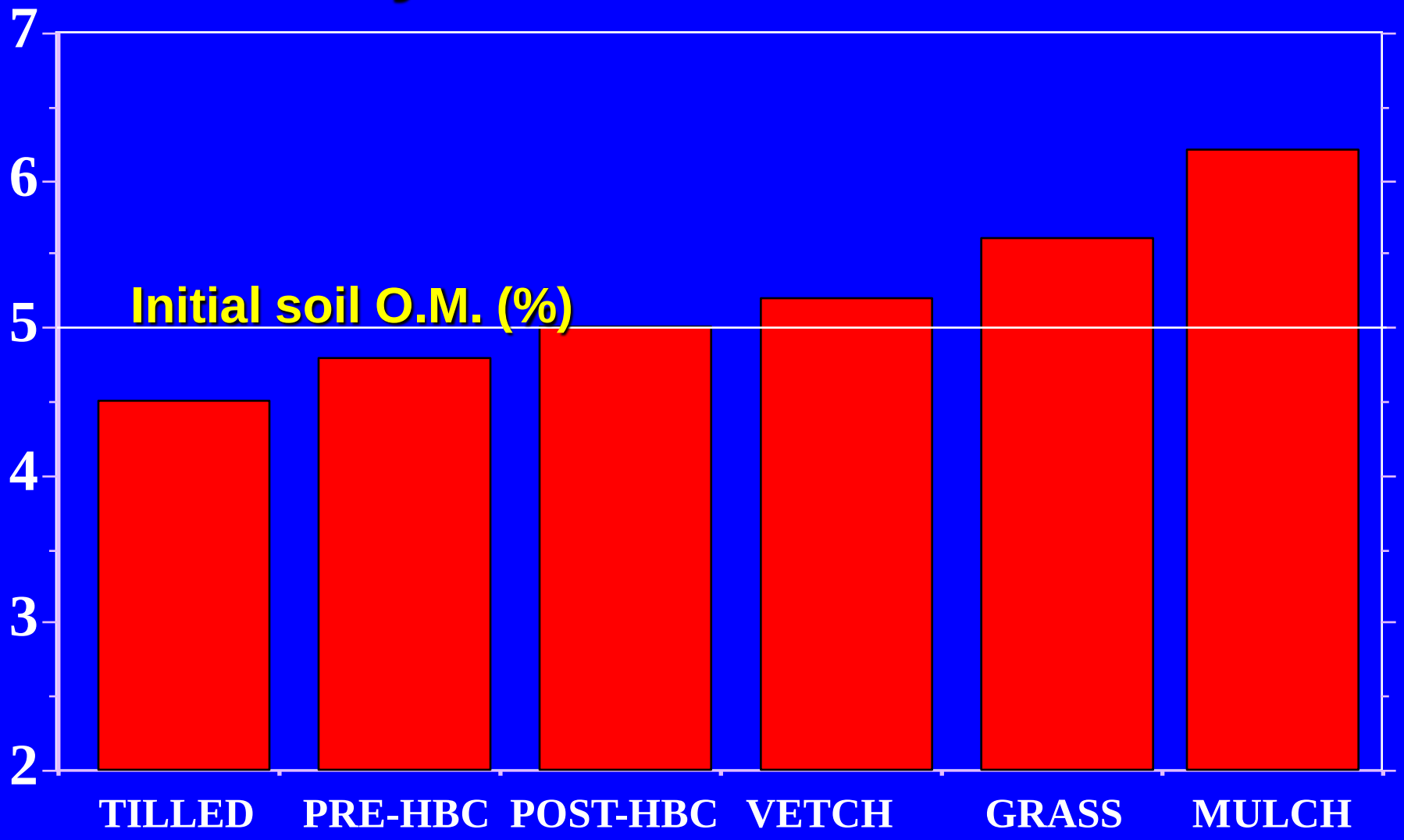
Fungal DNA fingerprints in rootzone soil from each GMS (Yao et al, 2005)





Mechanical cultivation with groundcovers in center of tree row (“Swiss sandwich system”)

Orchard Soil Organic Matter content (%) after six years under diffferent GMSs



Conclusions from GMS studies:

- GMSs influence long-term tree growth and yields: Mulch and post-emergence Glyphosate herbicide were the most effective, sustainable treatments
- Soil fertility and soil microbial activity increased over time under the composted bark mulch
- Nutrient and pesticide leaching & runoff were greater in the pre-emergence herbicide treatment, which lacked groundcover vegetation throughout the year
- Each GMS creates a distinct root-zone microbial community over time the orchard
- Sparse weed groundcover in the dormant season does not compete with fruit trees for nutrients, and helps to protect soil from erosion and nutrient loss

Orchard Groundcovers

- All cover crops may compete with fruit trees, but they can also suppress weeds and protect the soil
- Legume cover crops fix N, but also consume N and H2O, and are deep rooted & competitive with trees
- Dormant-season cover crops such as Annual Grasses or Mustards (*Brassica sp.*) can provide O.M. and N when mowed, tilled or treated with herbicides in Spring
- During orchard establishment, short-term crops such as hay and clovers can be grown in the alley ways without harming fruit trees, if the tree row strip is maintained
- Modern high-density orchards usually include a low-vigor turfgrass in the alley ways, and there are some very durable grasses available, mostly *Festuca sp*.

Brassica juncea cover crop—mid Winter and Spring

Different turfgrasses in a newly planted NY orchard

Apple Replant Disease:

A "soil health" problem usually controlled by preplant fumigation

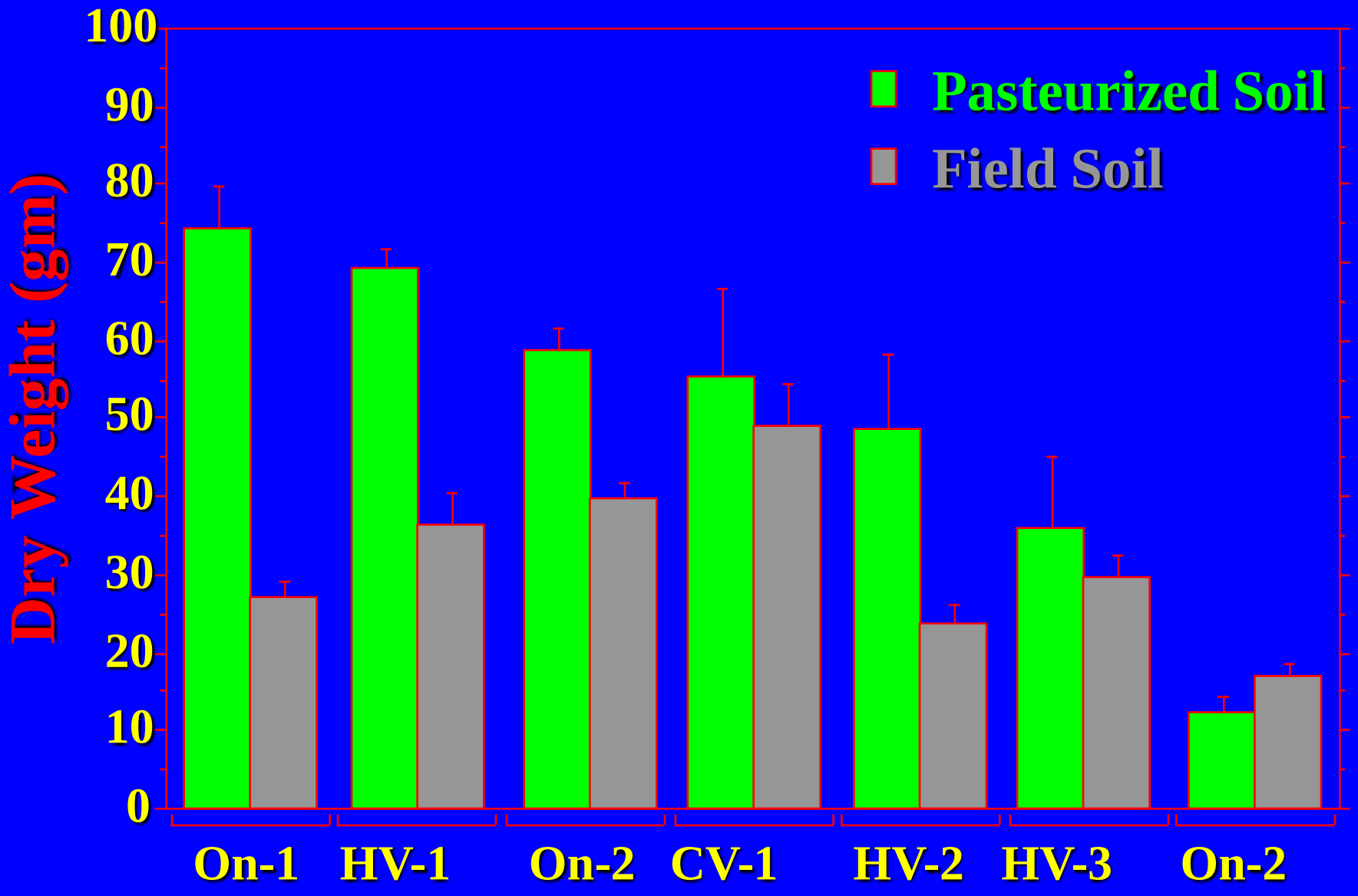
Apple Replant Disease (ARD)

- A soil-borne disease problem, young trees do not grow well
- Replant apple trees are stunted, poor growth & yields and greatly decreased profitability in new orchards
- New tree growth is usually worse in the old row locations
- ARD occurs in most orchards world-wide during replanting
- ARD is sometimes controlled by preplant soil fumigation, but this is expensive and not effective in every location
- Fumigation usually more effective in well drained gravel or sandy loam soils that have low organic matter content
- Diagnosing the extent and severity of ARD before replanting an orchard can save time and money

Soil samples can be steam-pasteurized at 85 C for 45 min, or fumigated to suppress ARD pathogens

Nursery soil bioassays can predict rootstock and apple tree responses to preplant soil fumigation or pasteurization at specific orchards

Tree bioassay growth in 7 NY orchard soils



What causes ARD?

Possible causes depend on the site:

- **Pathogens—Nematodes, Oomycetes, Fungi, Bacteria**
  Pratylenchus, Xiphinema, Meloidogyne…
  Phytophthora, Fusarium, Cylindrocarpon…
  Pseudomonas, Actrinobacteria…
- **Soil chemistry (pH too low or high, salinity)**
- **Soil Drainage (compaction, fragipan, topography)**
- **Soil nutrient depletion (deficient N, P, K, Cu, Zn, B)**
- **Combinations of pathogens (nematodes + fungi…)**

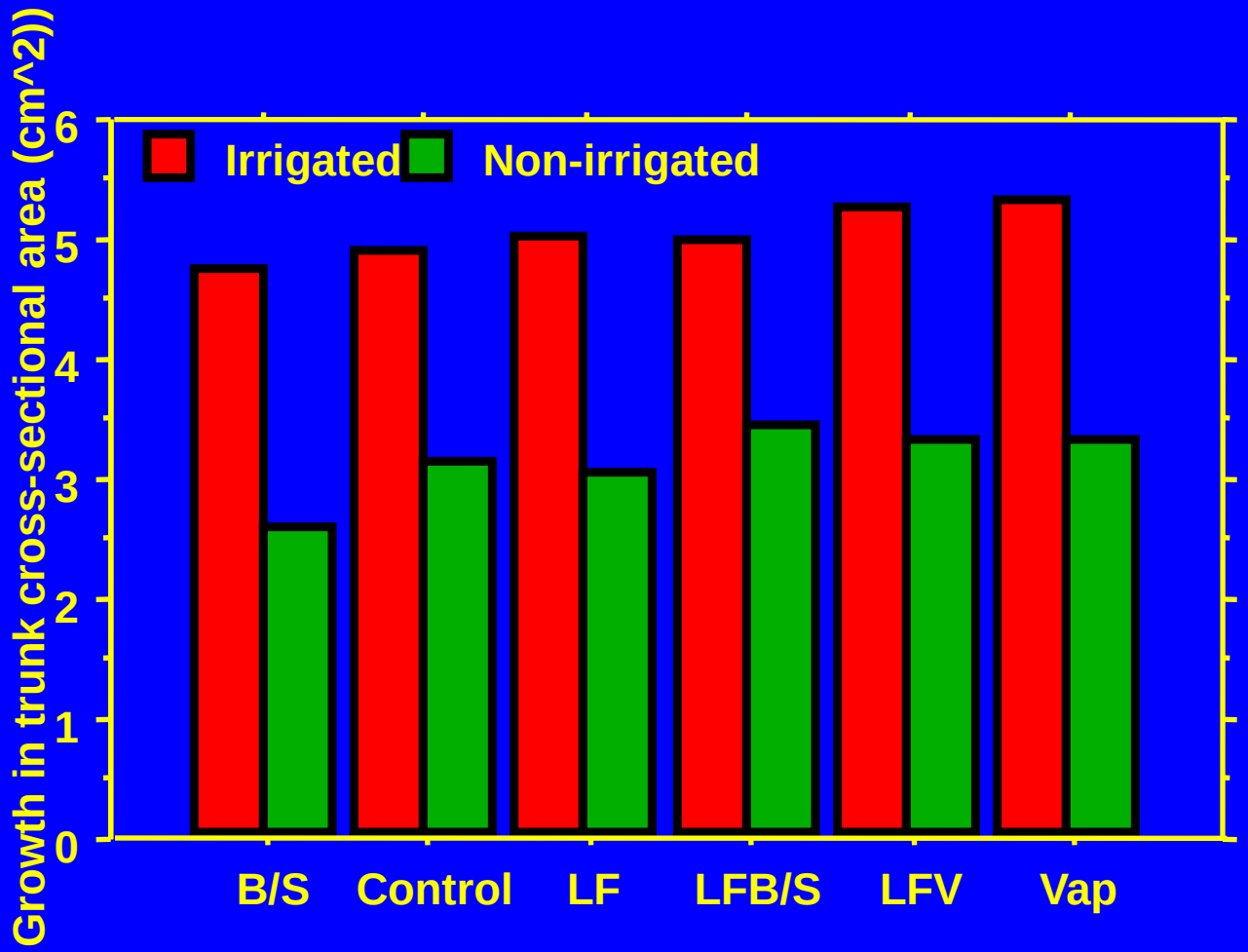
Preplant soil treatments for ARD

- **Broad spectrum soil fumigants**
  - **1-3-Dichloropropene (Telone) + Chloropicrin (17 or 35%)**
  - **Sodium-methyldithiocarbamate (Vapam HL)**
- **Preplant Cover Crops**
  - ***Brassica napa, B. juncea*—Canola, oilseed rape**
  - ***Sorghum X Sudanense*—Sudan grass hybrids**
- **Preplant fertilizer amendments**
  - **Nitrogen, Phosphorus, Potassium, Calcium, Magnesium**
  - **Biomass sources of organic matter (e.g. Sorghum sp.)**
  - **Manure, compost, "green manure" legume cover crops**

Preplant *Brassica juncea*, Hudson Valley orchard

Preplant Sudan Grass Cover Crop

Replant apple tree growth in 8 NY orchards, by Irrigation and Preplant soil treatments



Poor soil drainage in an orchard

Sub-soil drainage lines installed during orchard replanting

- Can be mechanized
- Costs about $5 per meter in New York orchards
- Minimizes problems with Phytophthora and Pythium root disease
- Improves nutrient (N-P-K) availability for trees
- Better access to trees for management and harvest

Can clonal rootstocks help to control orchard replant problems?

- Citrus: Poncirus, Citrumelo (*Tylenchulus* resistance)
- Peach Tree Short Life Resistance: (Guardian series)
- *Phytophthora* resistance: (M.9, B.9, CG series)
- Isutsa & Merwin (2000) CG.30, CG.6210, CG.16, and *M. sieversii* were resistant to ARD in NY orchards
- NC140 apple rootstock tests—most were replant sites and a few rootstocks usually performed better
- Comprehensive test of rootstocks, preplant treatments, and effect of replant tree location on severity of ARD

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

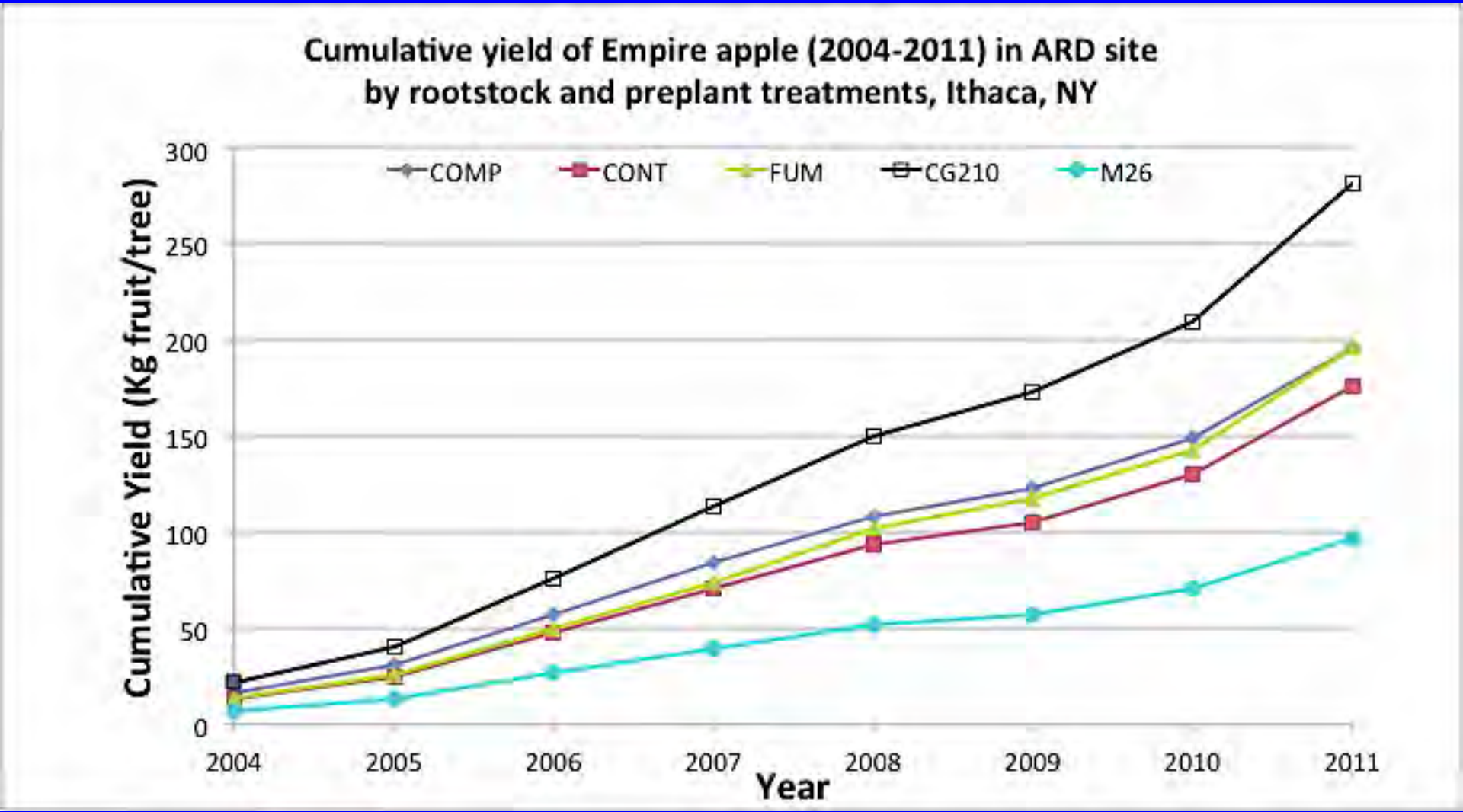
Combined test of different strategies for ARD:

- Planted new trees perpendicular to, and either in or out of the previous old tree rows at site
- Previous 80 yr old orchard, with severe ARD
- Organic compost soil amendment, 10 T per ha
- Fumigation with Telone C17 at 400 L per ha
- Five rootstocks: M7, M26, G16, G30, CG6210
- Experimental design enabled us to test rootstocks, fumigation, compost amendments, and tree planting locations as separate factors

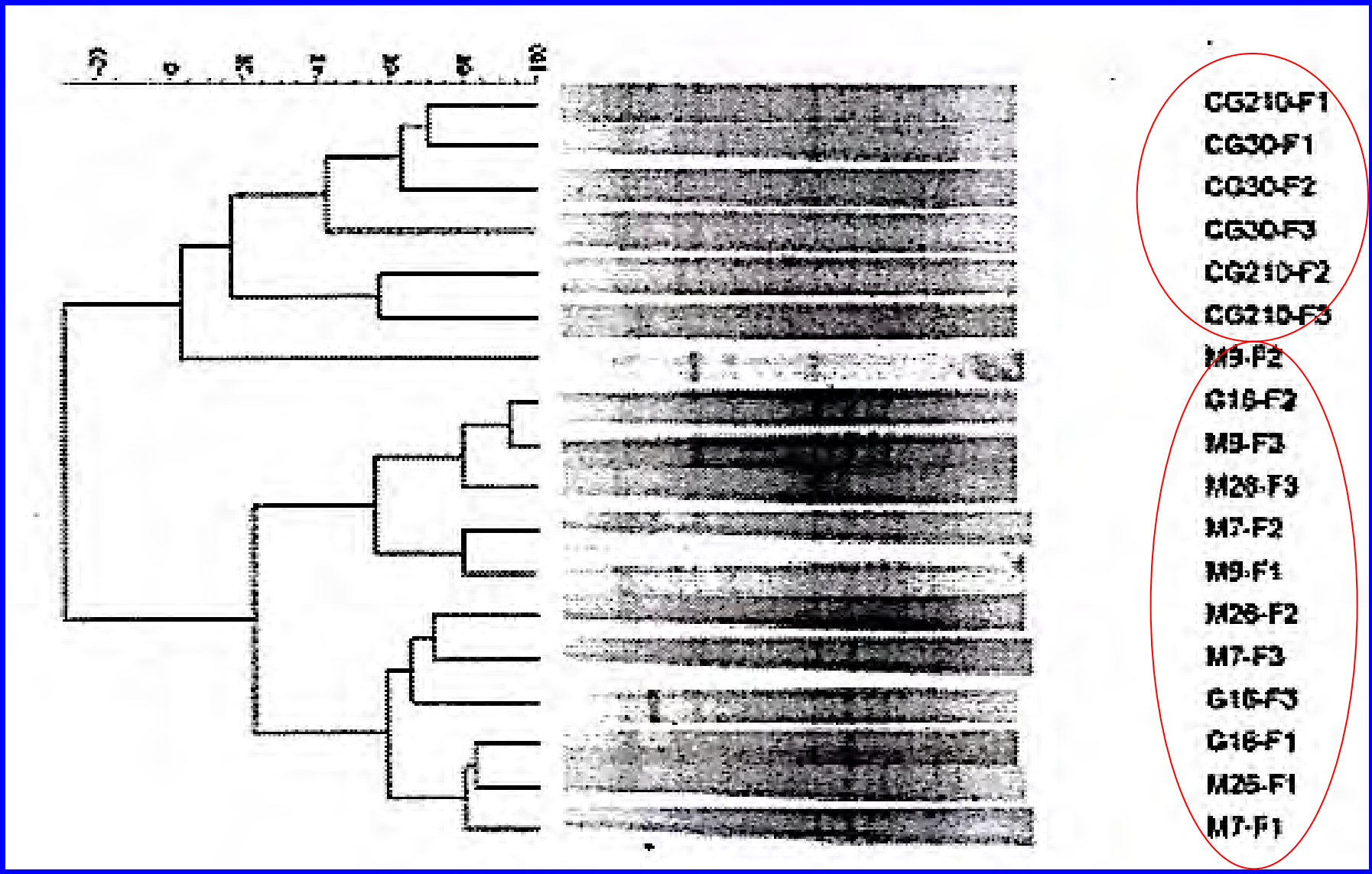
Old Tree Row vs. Old Grass Lane replant tree locations

A few years later…

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



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



CONCLUSIONS

- **Certain rootstocks (G41, G935, CG6210) are tolerant of replant disease, and perform well without soil treatments**
- **Rootstock clones exert genotypic effects on soil microbial communities in apple orchards**
- **Soil fumigation is not consistently effective for controlling ARD in all orchard soils and sites**
- **Planting new apple trees outside the locations of previous old trees is helpful to avoid ARD, but often not possible when changing from low to high density orchard systems**
- **Adding large amounts of compost or other organic soil amendments does not always improve replant tree growth**
- **Irrigation improves apple replant growth in most orchards**
- **In poorly drained soils, improving drainage, and planting trees on raised berms improves tree health and longevity**