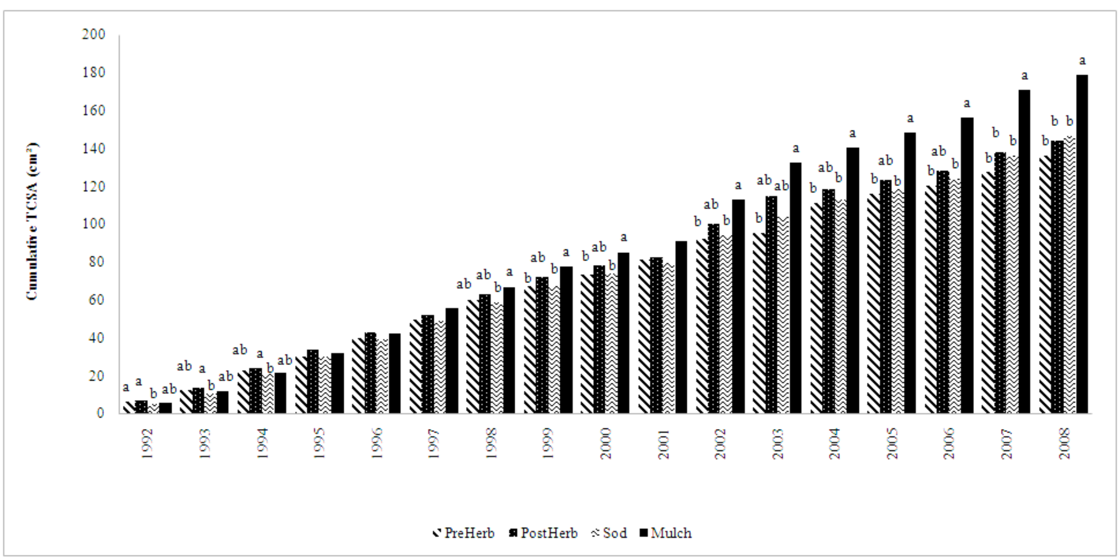
Wash. St. Hort. Assoc. Annnual Meeting 2013 Proceedings.

Soil Management Affects Orchard Soil Health and Tree Productivity

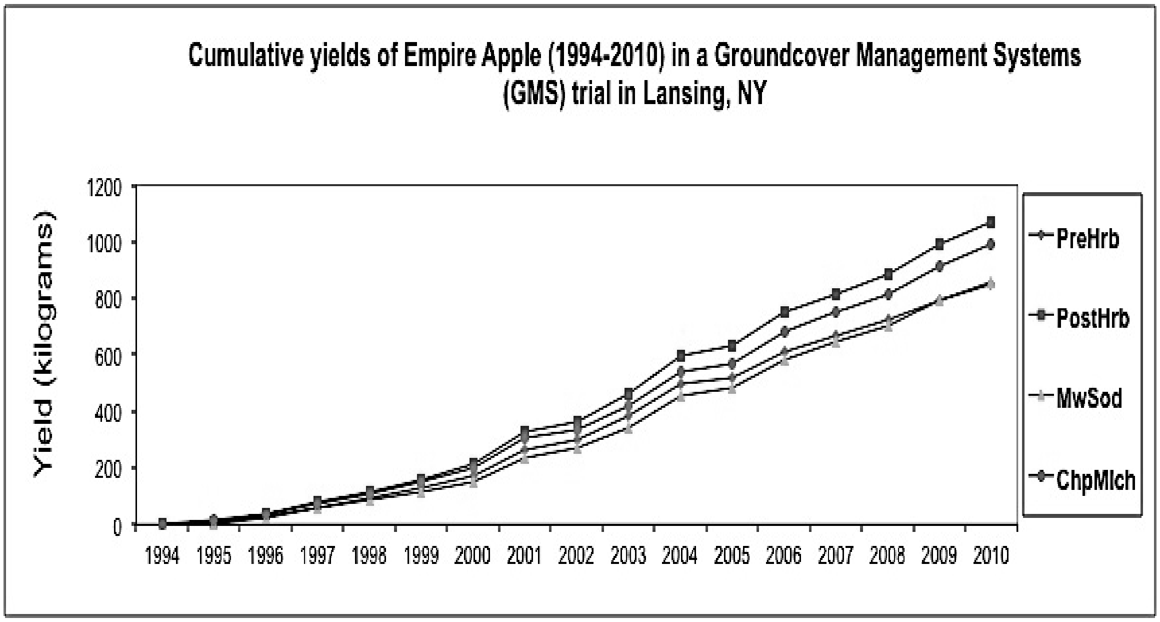
Ian A. Merwin
Dept. of Horticulture, Cornell University
Cornell University, Ithaca, NY, 14853
Email: im13@cornell.edu

Introduction. This talk covers research in my program at Cornell over a 20-year timespan. Many grad students contributed to this effort, including Michael G. Brown, Gregory M. Peck, Amaya Atucha, Shengrui Yao, and Michelle M. Leinfelder. I will present data from two long-term orchard experiments. The first was a 20-year comparison of four orchard groundcover management systems (GMSs) at a research farm in Lansing NY. This study compared soil biology, tree physiology and yields, nutrient budgets, and environmental impacts of these orchard GMSs, maintained in 6-ft-wide strips within the tree rows of a 2 acre planting of 'Empire' apple on M9/MM111 rootstocks, planted in 1992 at 6 by 18-ft spacing: The GMS treatments were: 1) A mowed red fescue turf-grass; 2) a composted hardwood bark mulch, applied every 2 years at a 4 inch depth; 3) glyphosate herbicide applied at standard labeled rates in May and July each year; and 4) a tank mixture of glyphosate, diuron and norflurazon herbicides applied in May each year. The entire orchard was planted on top of twelve below-ground drainage lysimeter grids (3 randomized replicates of the 4 GMSs) and included 12 runoff lysimeters as well. This setup enabled us to sample and measure the drainage and runoff water from each GMS plot, and we measured nitrogen, phosphorus, and agrichemicals concentrations in this water, to construct nutrient budgets for apple trees in each of the GMSs.

Tree growth and yields. Tree growth differed among GMSs during 18 years at this orchard (Figure 1, below).



During the initial four years, tree vigor (measured as trunk cross sectional area or TCSA) was greater in the two herbicide plots, while the trees growing in mowed sod plots were about 40% smaller than those in herbicide plots. However, during the next five years there were few significant differences in tree growth among the GMSs, as the trees adapted to each floor management system. Beginning in 1999, a long-term trend emerged and trees in composted bark mulch plots were the most vigorous. However, these differences in tree size did not correspond with cumulative yields of trees in the four GMSs (Fig. 2, below). The long-term trend was that trees in the post-emergence glyphosate (PostHrb) and the barkchip mulch (ChpMlch) produced more fruit than trees in preemergence herbicide (PreHrb) and mowed sod (MwSod) plots. The most common GMS used in NY orchards—a mixture of pre and post emergence herbicides that



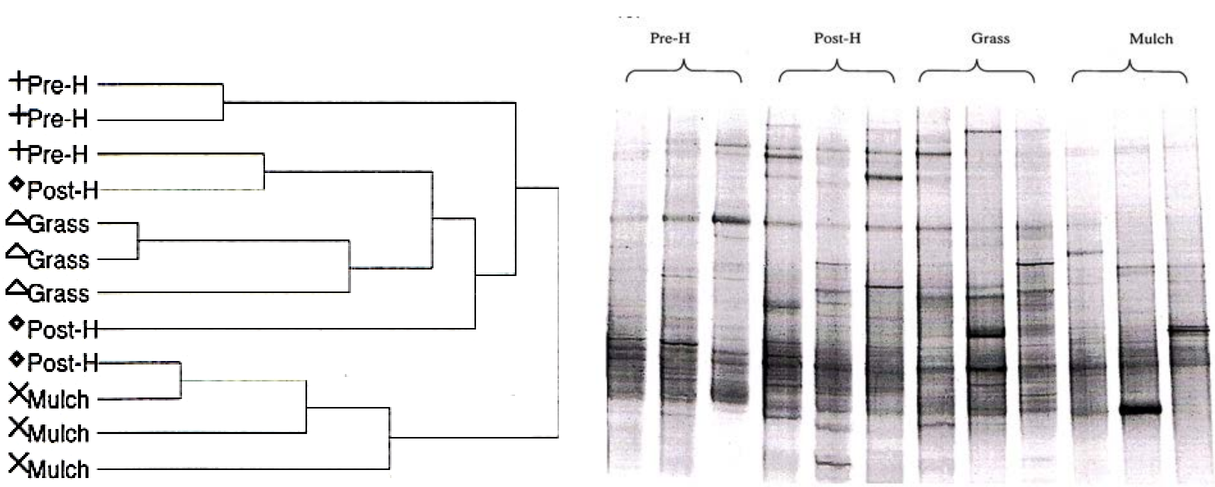
maintains a weed-free strip beneath trees—was <u>not</u> the most productive GMS over time. The weed free pre-emergence herbicide trees were less productive than those in PostHrb and ChpMlch treatments, despite the fact that the latter two treatments had substantial weed populations in the tree rows from late summer through the winter dormant season each year.

Soil fertility and root-zone microbial communities under different GMSs. The long-term differences in soil fertility were substantial among these GMSs. Available soil P concentrations tripled under the bark mulch compared with the other three GMSs. Soil Ca concentrations doubled under bark mulch compared with the other treatments, and soil pH was higher under the bark mulch. Soil organic matter doubled under the bark mulch, and cation exchange capacity was about 75% higher under mulch compared with the other three treatments (Table 1, below). These increases in soil fertility most likely explained the stronger tree growth in mulch compared with the other GMSs, and it appears that composted bark mulch is an excellent orchard floor management system for orchards on soils with limited fertility, where nutrient deficiencies and limited tree growth are problematic.

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.

We measured soil respiration and used molecular DNA and RNA "fingerprint" methods to quantify soil microbial activity and compare the fungal communities inhabiting root-zones of trees in each of the GMSs, after 15 years of each treatment. Microbial respiration measures "biological activity" and potential nutrient mineralization rates in the soil. The rate of microbial activity was greater and more sustained in soil under bark mulch (data not shown). The DNA fingerprints also revealed clear differences in fungal communities around tree roots (Fig 3, below). Except for the glyphosate treatment, each GMS induced a different fungal community around the roots of apple trees, as shown by the DNA "tree" in the dendrogram below. Treatments at the ends of the same branches in this figure have similar fungal communities. Interestingly, the root fungal community in glyphosate (PostHrb) plots was diverse and scattered among the other three GMSs. This diverse root-zone fungal community may be related to the greater yields and sustained tree vigor of trees growing in the glyphosate treatment.

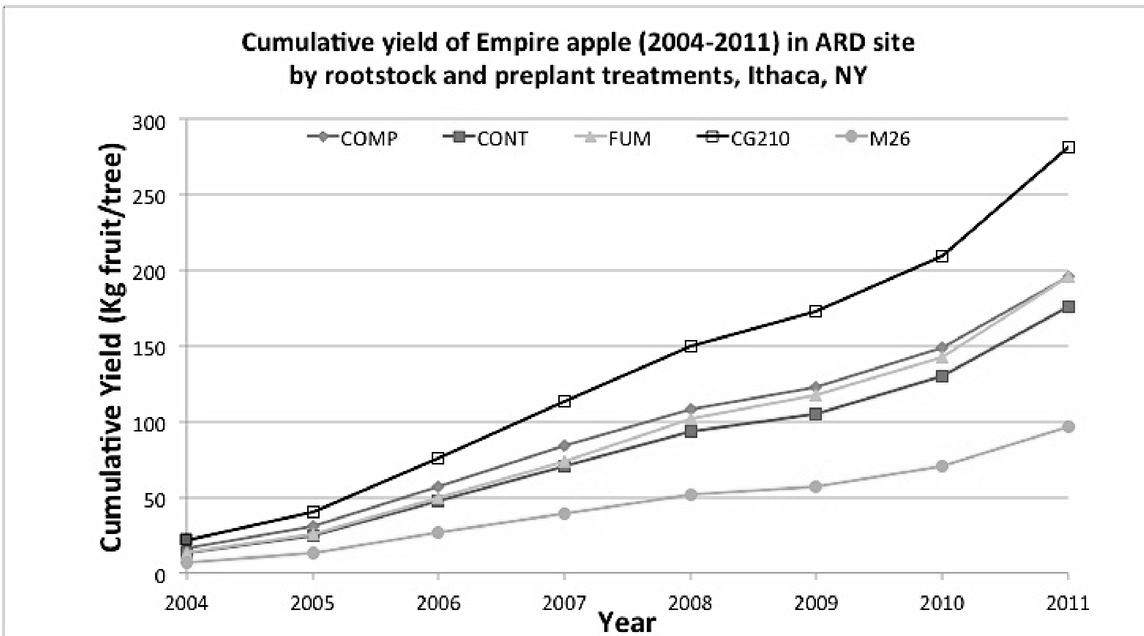


Nitrogen budgets for trees in each GMS. Nutrient budgets are helpful to understand whether an orchard is in balance, running deficits, or wasting fertilizer and money due to excessive nutrient supply. Other researchers (including Dr. Lailiang Cheng at Cornell) have constructed nitrogen budgets for apple trees grown in sand culture with controlled nutrient supply, but there was no information available on the actual nitrogen budgets for apple trees growing under different GMSs in commercial orchards. We were able to construct a nitrogen budget for trees in each GMS at this orchard, pulling together information about soil N supply, N recycling from groundcover vegetation, bark mulch residues and soil organic matter mineralization, inputs from irrigation water and precipitation, and N losses through soil runoff and leaching. These data are shown below (Table 2), as published recently in the journal HortScience (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)†

This table shows data for the year 2005, when 60 lbs N per acre was applied in the orchard, and the year 2007 when no N fertilizer was applied; the important trends are circled. It's worth noting that the bark mulch input represents a very large amount of N (averaging more than 100 lbs N/acre over the final years of observation). Also, the internal cycling of N in pruned wood, tree leaf drop, and soil organic matter mineralization were all substantial, ranging from 52 to 87 lbs N per acre over the two years in this orchard. Subtracting the N outputs in leaching, runoff, and harvested fruit each year from the N inputs and internal fluxes shows the annual net N balance or "budget" for this orchard in each GMS. The bottom line shows that all of the treatments in both 2005 and 2007 provided more than enough N for apple trees in this orchard, despite the significant differences in N balance among the four GMSs.

Soil health and apple replant disease. For 25 years we conducted orchard tests of alternative control methods for apple replant disease (ARD). This is a widespread and chronic soil health problem that often stunts the growth and yields of newly planted apple trees in old orchard sites. In 2001 we established a test orchard to compare the effects of preplant soil treatments and rootstocks at an orchard in Ithaca NY where previous apple trees had suffered from replant disease. The preplant treatments included compost amendments, fumigation with Telone C17, and a check treatment. New trees were replanted either within the previous orchard tree rows, or in the grass drivelanes; and replanted trees ('Empire') were grafted onto either M.26, M.7, G.30, or G.210 rootstocks. After ten years of observations, the treatment effects on cumulative fruit yields were interesting and quite clear (Fig 4, below).



Cumulative tree yields were not significantly different among the compost, fumigation, and untreated control treatments. The important differences were among rootstocks. Trees on CG.210 produced more than twice as much fruit as those on M.26. In other words, planting new trees on the right rootstock was much more helpful than investing in preplant fumigation or compost soil amendments at this replant site. We also did DNA fingerprints of fungal communities on each rootstock, and the ARD resistant rootstocks (CG.210 and G.30) had distinctly different rhizosphere microbial communities than the more ARD susceptible rootstocks M.7 and M.26 (data not shown).

The main points of this presentation are:

- Bark mulch optimizes soil fertility, OM, biological activity & tree growth vs. other GMSs
- Over 18 years apple trees adapted to each soil management system, and cumulative yields were surprisingly similar in the long-term, though greater in glyphosate and bark mulch.
- A weed-free preemergence herbicide GMS was no more productive than mowed sod-grass, and had higher nutrient leaching and runoff compared with the other systems.
- Each GMS promoted a different microbial community in the root zone of apple trees.
- Some Cornell/Geneva rootstocks are tolerant of replant disease, a soil health problem.