Understanding the complexities of soil health in berry crops

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Niagara County Vegetable & Small Fruit Grower Meeting,

Lockport, NY

March 1st, 2016

Strawberry Black Root Rot
Symptoms

- **Patchy-complete blackening of main/perennial roots**
- **Deterioration of perennial & feeder roots**
- **Smaller root systems**

Strawberry Black Root Rot
Field Symptoms

- **Above ground structure stunted, reddened & collapsed**
- **Wilting of leaves**
- **Lack of runnering**
- **Decline of vigor & productivity**

Biotic, edaphic and cultural factors associated with strawberry black root rot in New York (1995). K.Wing, M.Pritts and W. Wilcox.

- Survey of 27 farms
- Two locations per farm
- 104 variables (cultural, historical, physical, chemical)
- Root health – dependent variable

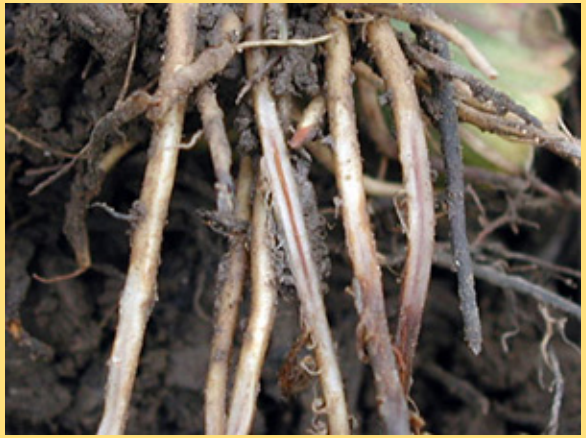
Factors most highly correlated with poor root health

- Age of plantings
- Cumulative years in strawberry production
- Soil compaction
- Fine soil texture
- Absence of raised beds
- High application rates of terbacil
- Non-use of metalaxyl
- Frequency of fumigation

- Thus began a 20-year quest to understand the individual effects of biological, physical and chemical factors on root health
- Complicated by the fact that these factors interact with each other
  - Some may be direct causes of poor root health
  - Others may create conditions that allow for the direct causes to become manifest

Phytophthora

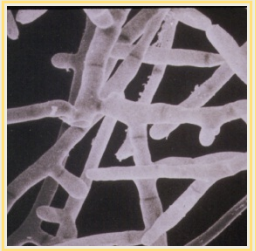
- At least 10 races of the disease exist - resistance to one race does not confer resistance to another.
- Persistent in soil for many years
- Distinctive symptoms (red stele)



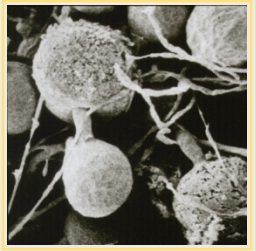
Common pathogens in berry fields

- *Pratylenchus penetrans*

- *Rhizoctonia* spp



- *Pythium* spp.



Other associated organisms

- *Verticillium albo-atrum*
- *Fusarium* spp.
- *Cylindrocarpon* spp.
- *Phytophthora* spp.
- *Idriella lunata*
- Others

Pythium

- Associated with poor establishment and decline of many fruit and vegetable crops
- Twenty purported species have been isolated from strawberry roots
- These vary in pathogenicity
- Tends to be associated with cooler, wetter soils
- No unambiguous diagnostic symptoms

Rhizoctonia

- At least two species are pathogenic
- Three groups within the most virulent species
- All cause symptoms in strawberry
- Tends to be associated with warmer soils
- No unambiguous diagnostic symptoms

Challenges in diagnosis and management

- These species are often isolated from healthy root systems
- Can occur together and behave synergistically
- Genetic differences in tolerance exist, but ratings of cultivar resistance vary depending on the location of the study
- Low levels of *Rhizoctonia* infection can be beneficial under certain conditions

- Wing, K. B., M.P. Pritts and W.F. Wilcox. 1995. Field resistance of 20 strawberry cultivars to black root rot. *Fruit Varieties Journal* 49:94-98.

- Scott, R., Pritts, M. and M. J. Kelly. 2004. Effects of *Rhizoctonia fragariae* infection on growth and productivity of strawberry plants grown under different temperature regimes. *Adv. in Strawberry Research* 22:26–33

Strategies to manage root health

- Eliminate the pathogens (fumigation/fungicides)
- Prevent the introduction of pathogens
- **Prevent the establishment of pathogens**
  - Managing the physical environment
  - Managing the chemical environment
  - Managing soil biology

I. Manage the physical environment

- Raised beds
- Mulch
- Compaction


Raised bed
Flat bed

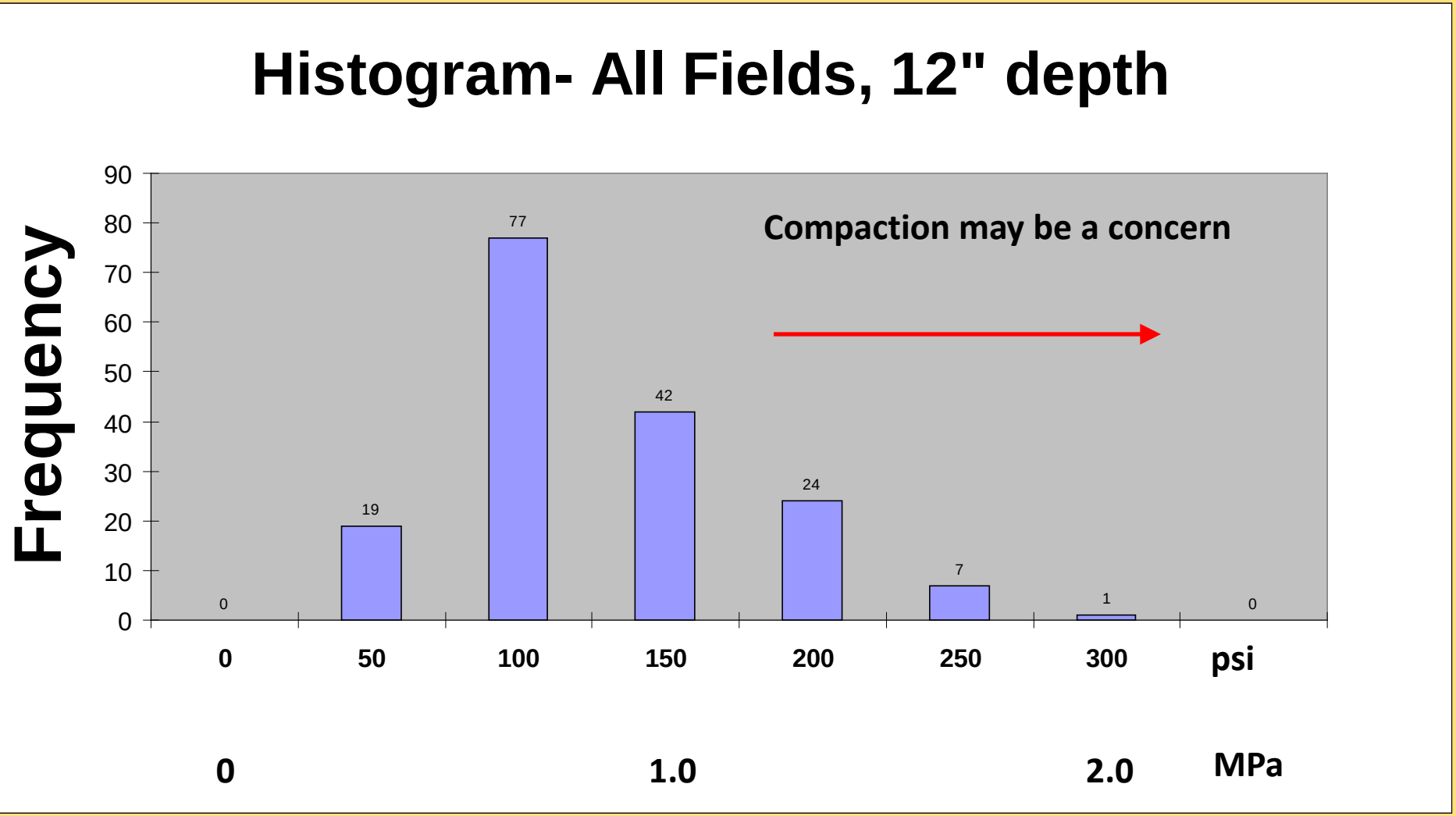
Factor	Level	% diseased canes	Yield/plot (kg)
Cultivar	Newburgh	4.8	3.79
	Titan	46.1	0.28
Bed height	Raised	17.2	3.03
	Flat	33.7	1.04
Straw mulch	Yes	51.0	1.81
	No	19.1	2.09
Metalaxyl	Yes	14.2	2.33
	No	33.0	1.83

Wilcox, W.F., M.P. Pritts and M.J. Kelly. 1999. Integrated control of Phytophthora root rot of red raspberry. Plant Disease 83:1149-1154.


MOWED
DWARF
PERENNIAL
RYE

Compaction

Distribution of compaction readings at 10 sites in 17 commercial strawberry fields



Experiment (2004)

- Virgin site with excellent drainage
- Three levels (whole plots) of preplant soil compaction (none, moderate, heavy) plus no preplant compaction with subsequent subsoiling
- Subplots consisted of three maintenance levels for three years (no tractors, light equipment, heavy equipment)

Mike on the Rhino . . .


STANLEY

Bulk density
Macroporosity
Mesoporosity
Microporosity
Residual porosity

Preplant treatment effects on soil were still observable after three years
Penetrometer readings (2006 data)

	Soil depth (cm)					
Treatment	8	16	24	32	40	48
Subsoil	89	97	117	182	264	298
Minimum	158	234	247	256	269	322
Moderate	198	253	252	263	283	312
Maximum	210	272	295	302	317	344

Bulk densities of 1.35 – 1.65 g/cm3

Post-plant treatment effects on soil were maintained after three years (2006 data)

	Soil depth (cm)					
Treatment	8	16	24	32	40	48
Minimum	104	155	178	211	249	289
Moderate	152	212	225	234	264	299
Maximum	236	277	281	308	338	370

Preplant treatments had an impact on runner production and yield in the first fruiting year.

Treatment	Daughter plants* (#/m)	Yield* (kg/4 m)	Individual fruit weight (g)
Minimum	44.0	7.83	12.0
Moderate	31.0	7.73	12.2
Maximum	28.6	7.19	12.1

A similar trend was continued into 2006, but the impact was not large (<10%).

Treatment	Yield* (kg/4 m)	Individual fruit weight* (g)
Minimum	22.0	13.9
Moderate	21.2	12.4
Maximum	20.3	12.7

No differences were found from post-plant treatments in the first fruiting year.

Treatment	Daughter plants (#/m)	Yield (kg/4 m)	Individual fruit weight (g)
Minimum	35.7	7.47	12.1
Moderate	31.0	7.90	12.0
Maximum	36.7	7.38	12.2

Post-plant treatments had an impact only on individual fruit weight after 3 years.

Treatment	Yield (kg/4 m)	Individual fruit weight (g)*
Minimum	20.7	13.6
Moderate	21.3	13.0
Maximum	21.7	12.6

The most compacted treatments still supported extremely high yields (for the Northeast)

38,000 lbs/acre or 43 tons/ha

Conclusions:

Plant health, yield and fruit size are greatest in uncompacted soils

but

In the absence of poor drainage and on a virgin site, strawberries are remarkably tolerant of soil compaction (up to 1.7 g/cm3)

Pritts, M.P. and M.J. Kelly. 2008. Effect of soil compaction on strawberry root health and yield. Proc. 2007 North American Strawberry Conf. Ventura, California

II. Manage the chemical environment

- Does soil pH and compost affect the incidence of Phytophthora?

- Maloney, K., M. Pritts, W. Wilcox and M. Kelly. 2005. Suppression of Phytophthora root rot in red raspberries with cultural practices and soil amendments. HortScience 40:1790 – 1795.

Preplant treatments (raspberries)

- **Calcitic lime**
- **Dolomitic lime**
- **Calcium sulfate**
- **Manure compost**
- **Brewery compost**
- **Ammonium nitrate**
- **Phosphorus acid**
- **Ridomil**
- **Raised bed**
- **Control**

Adjacent plantings of a virgin and replant site

Replant site

Virgin site


Virgin site


Replant site

1995 fruit yield as % of control

Treatment	Replant site	Virgin site
Phosphorus acid	152	80
Gypsum	147	128
Ridomil	118	123
Dolomitic lime	117	115
Ammonium nitrate	99	120
Raised beds	97	111
Calcitic lime	91	98
Manure compost	75	98
Brewery compost	68	60

Preplant soil amendments

- Calcium sulfate (3 t/ha)
- Calcium sulfate (6 t/ha)
- Calcium chloride
- Potassium sulfate
- Sulfur
- Control

Results:

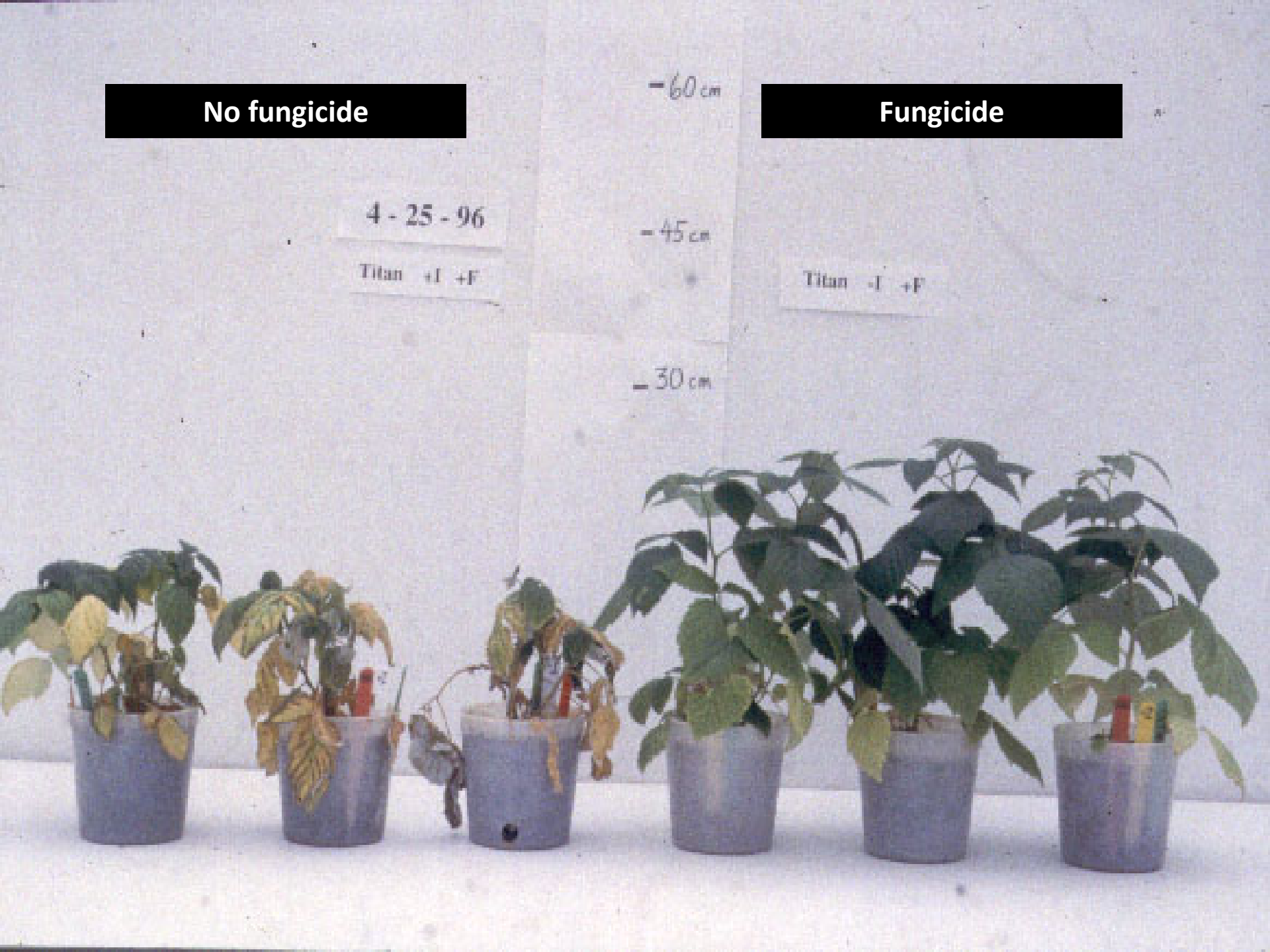
Treatment	Cane density
Control	14.0
K2SO4	15.5
S	18.5
CaSO4 (6 t)	22.8*
CaSO4 (3 t)	24.6*

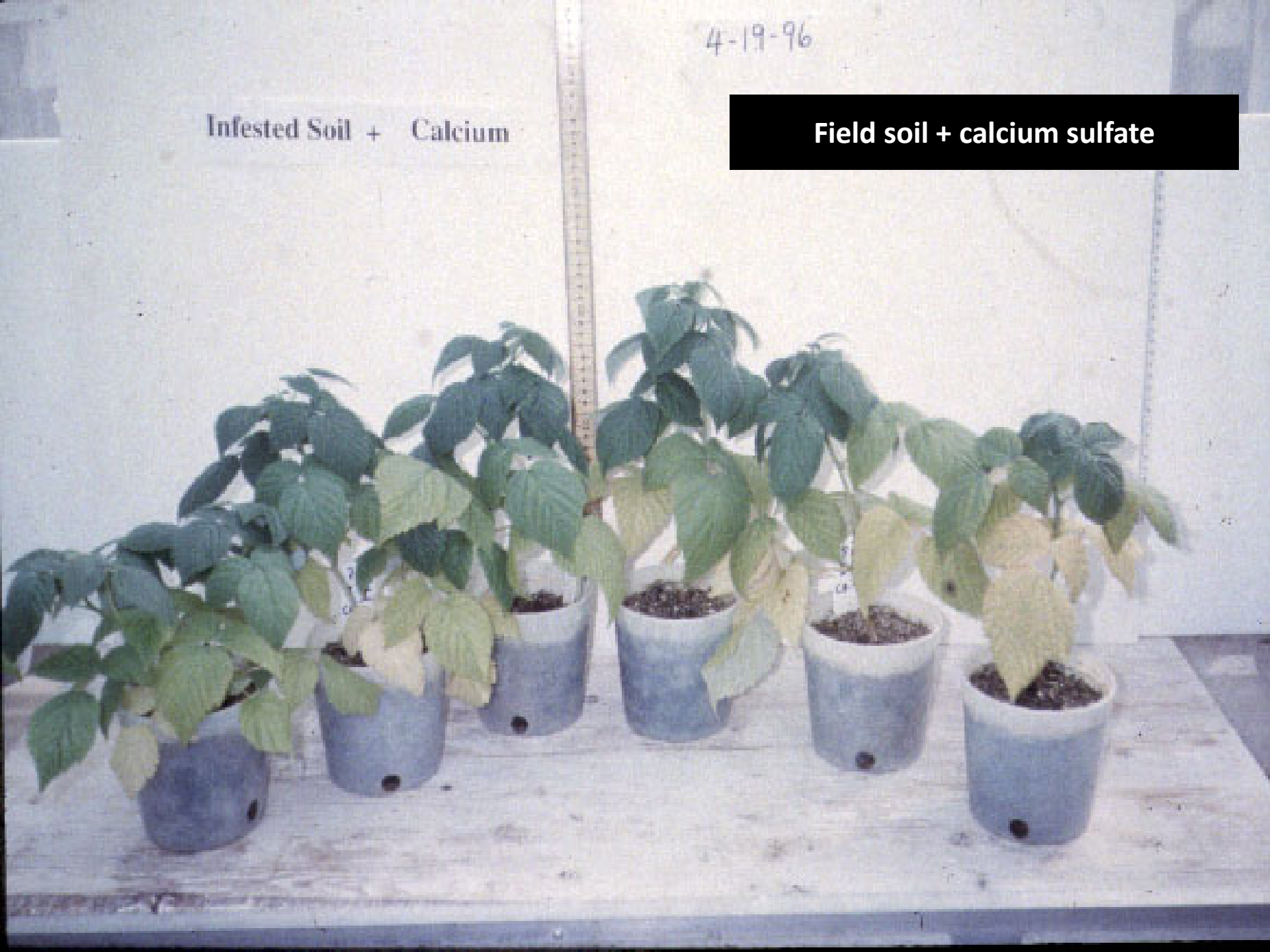
Greenhouse experiment

- Field soil
- Sterilized field soil
- Ridomil + field soil
- Calcium sulfate + field soil

Field soil flooded


Field soil, sterilized
4-19-96
Infested Soil
Sterilized


No fungicide
Fungicide
4 - 25 - 96
Titan -I +F
Titan -I +F
60 cm
45 cm
30 cm


4-19-96
Infested Soil + Calcium
Field soil + calcium sulfate

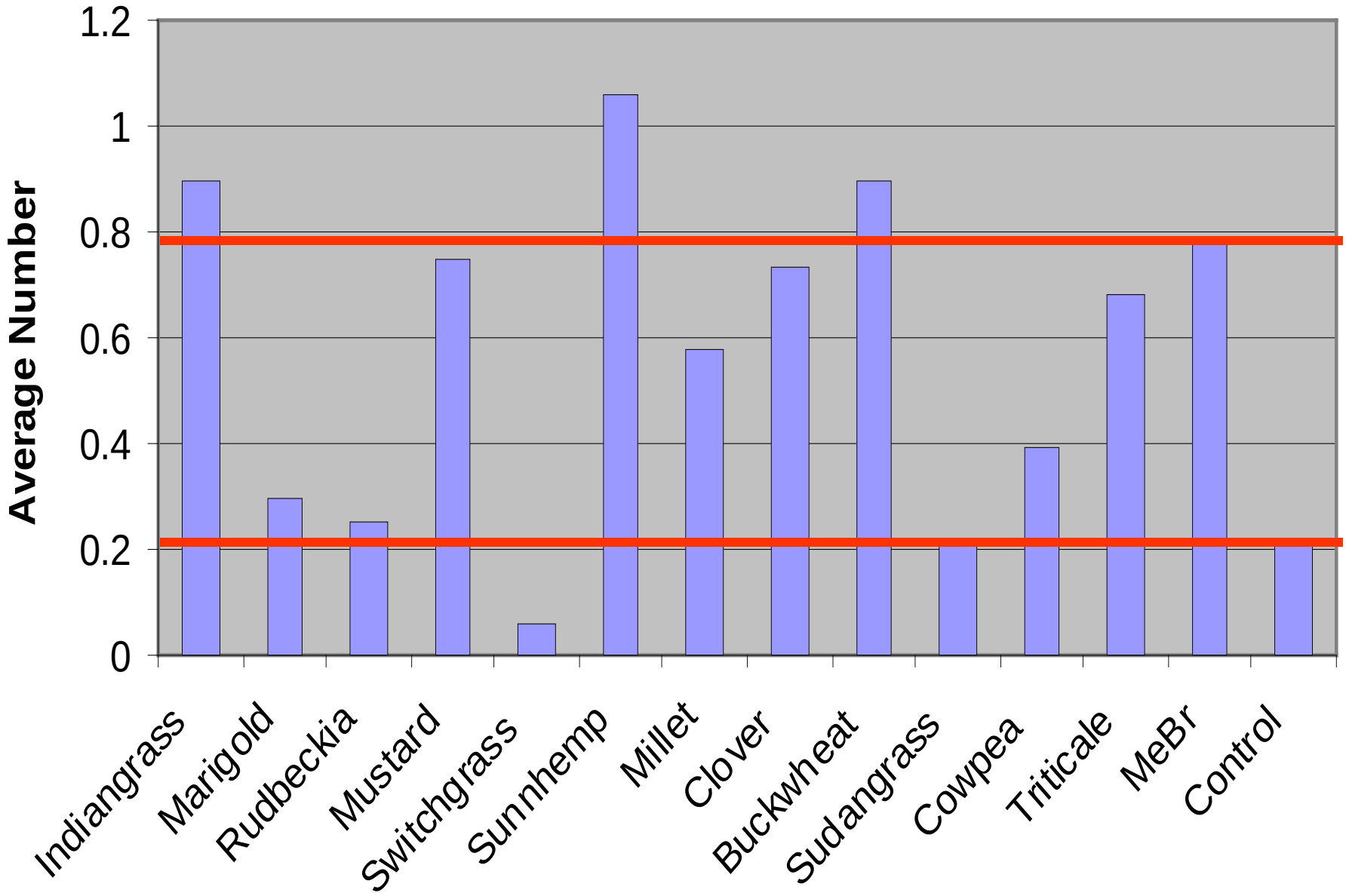
- Calcium sulfate amendments positively impacted the health of raspberry soils by suppressing the activity of Phytophthora.
- This effect was independent of pH or a direct effect of calcium on plant growth.

III. Manage the soil biology

- Rotations

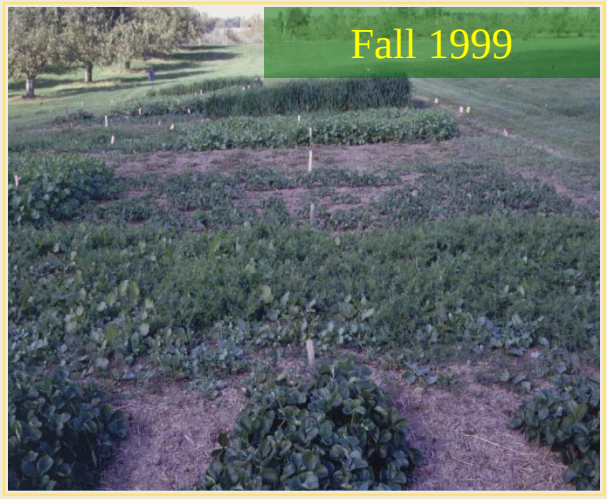
Seigies, A.T., M.P. Pritts and M.J. Kelly. 2006. Cover crop rotations alter soil microbiology and reduce replant disorders in strawberry. HortScience 41:1303-1308.

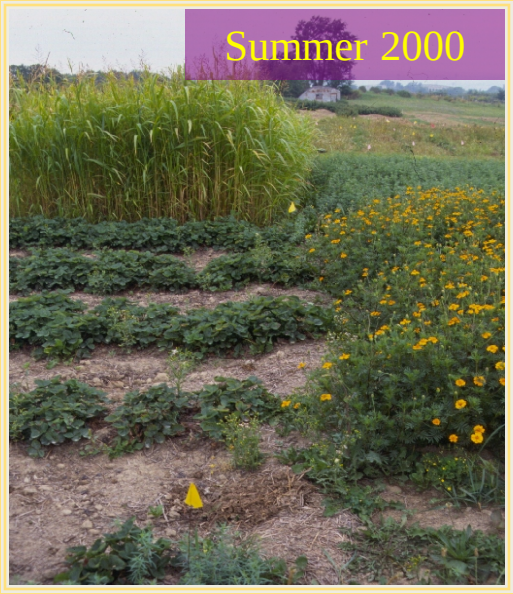
Runner Count 2003



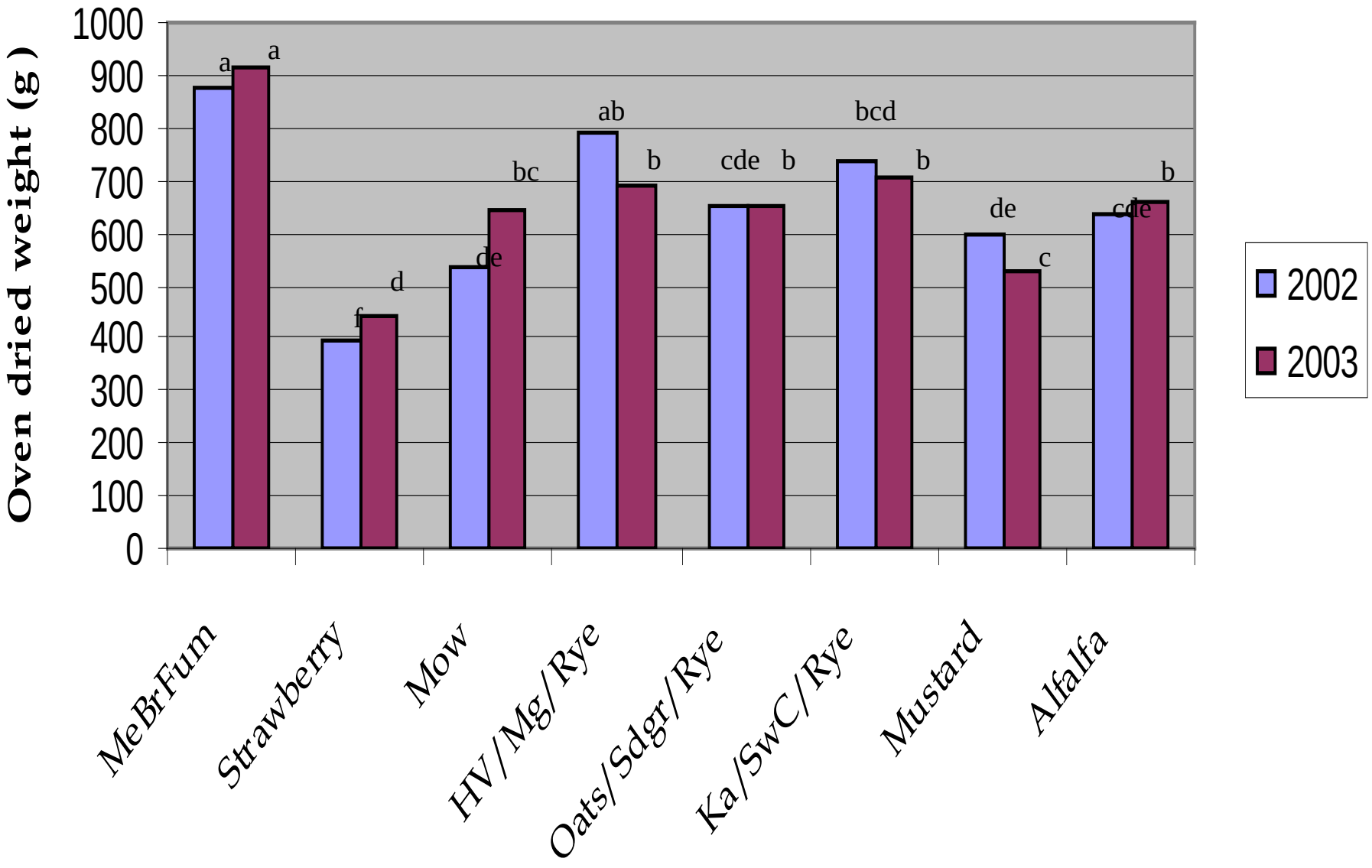
Materials & Methods
Field Study

- Experimental Design
  - RCBD
  - Eight Treatments (following 7 years in strawberry):
    - Continuous Strawberry (2 more years)
    - Mowed Weedy Fallow
    - Fumigation (MeBr)
    - Alfalfa (perennial)
    - Mustard (3 crops)
    - Kale→ Sweet Corn →Rye
    - Hairy Vetch →Marigold →Rye
    - Oats →Sudangrass →Rye
  - Four Replicate Blocks
  - Rotations August 1999 →April 2001

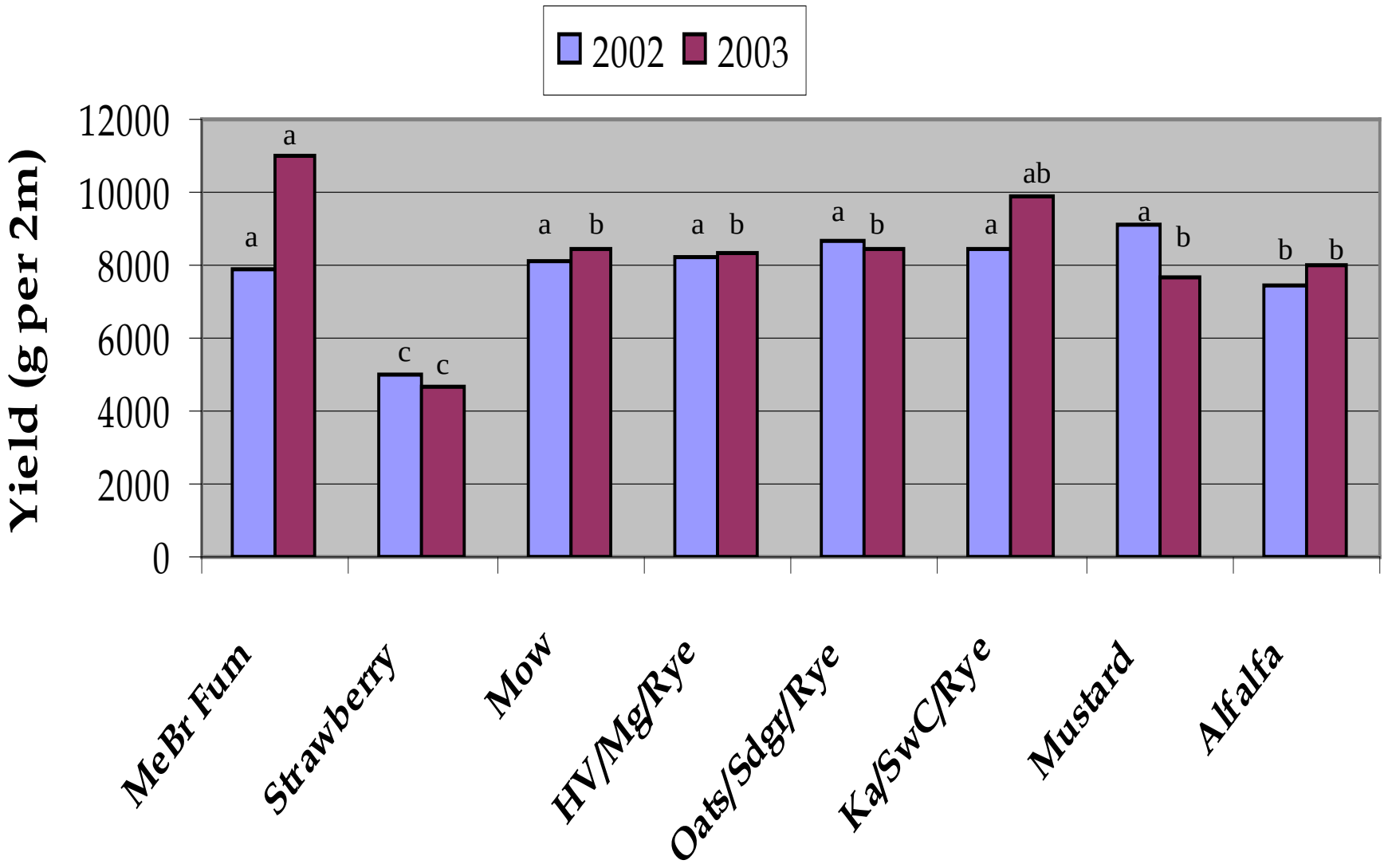




Foliar Biomass



Fruit Yield 2002 & 2003



USDA-funded project: An integrated approach

- Six farms (New York, Maryland, Michigan)
- Factorial experiment

  Cultivar (Allstar and Cavendish)

  +/- fumigation

  +/- compost amendment

  +/- fungicidal preplant root dip


12 9'03

Control – No amendments or preplant treatment

Fumigation

Compost: No other amendments

Cover crop – No fumigation

Untreated

Fumigation

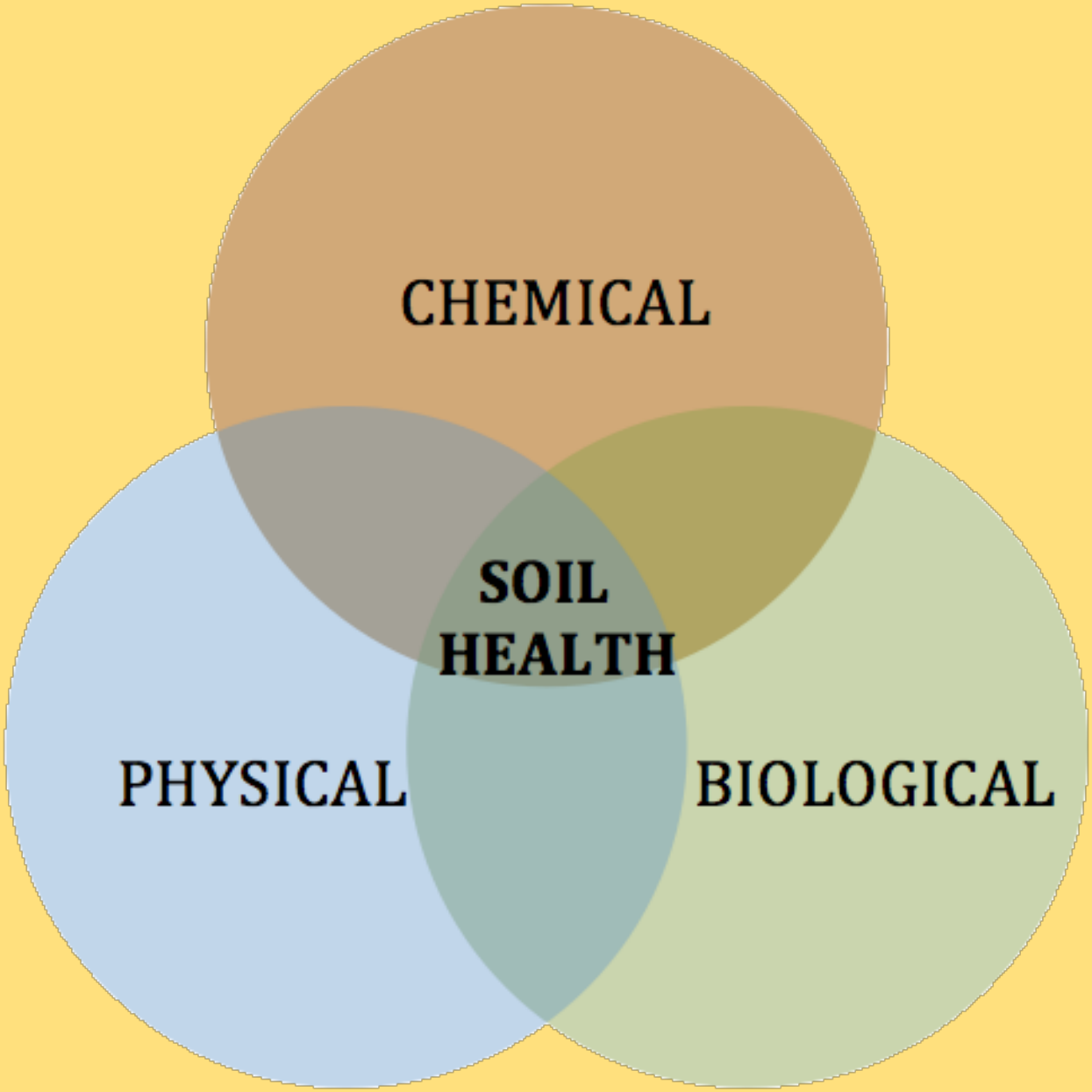
Compost amendment

Trends

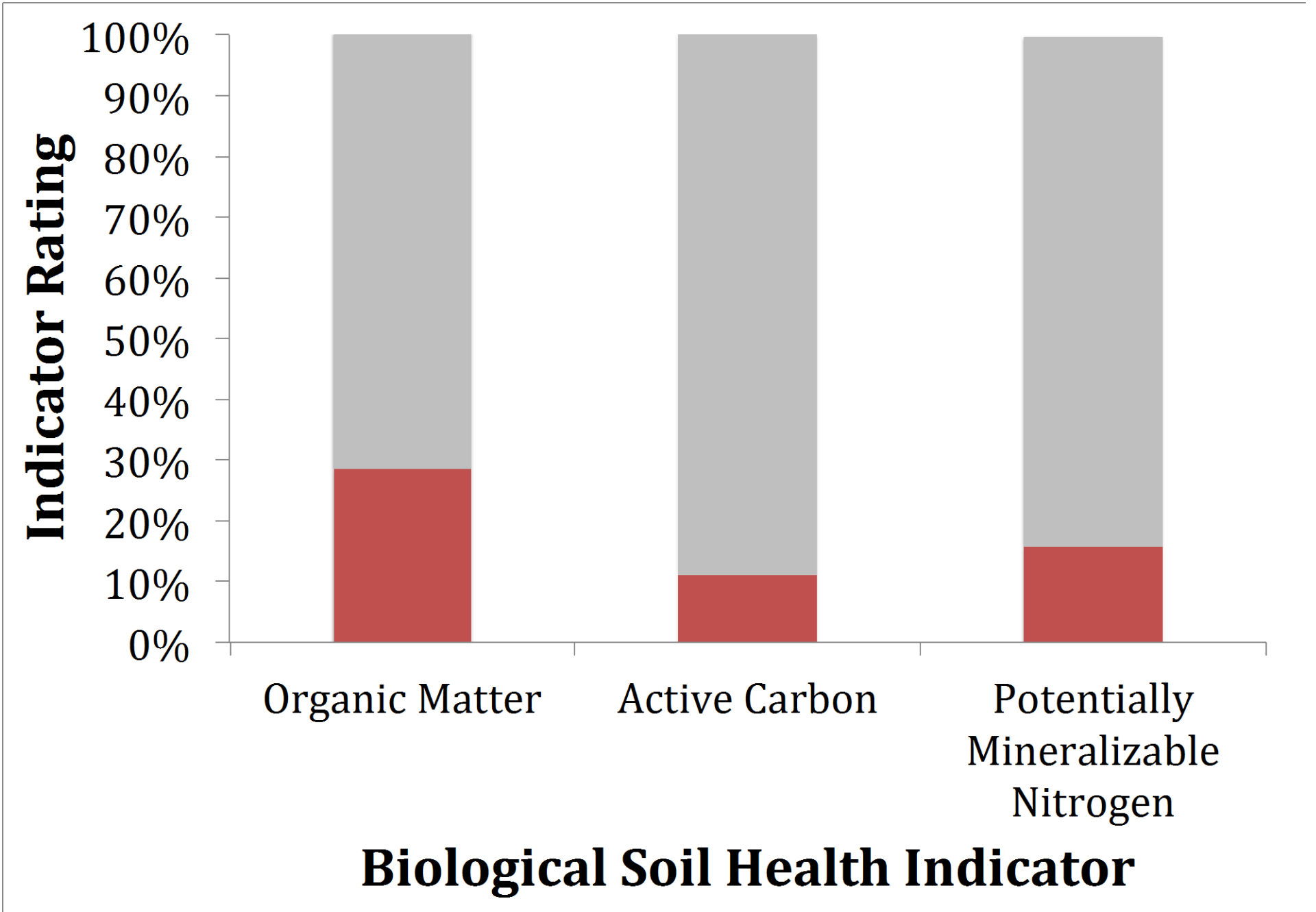
1. Continuous strawberry increases replant disorders
2. Mixed rotations and certain preplant cover crops can have
   - significantly reduced fungal CFUs & weediness
   - similar effect as MeBr on increasing yield & biomass

It’s hard to go wrong with . . .

- Crop rotation (out of berries for several years)
- Modest compost incorporation prior to planting
- Cover cropping prior to planting
- Coupled with improvements to drainage and nutrient amendments as appropriate


CHEMICAL
SOIL
HEALTH
PHYSICAL
BIOLOGICAL

NE SARE survey of strawberry farms (2012)



- Strawberry fields had consistently low indicators of biological soil health (active carbon, PMN)
- Adjacent vegetable fields did not show these consistently low values
- What is different about the management of strawberries vs. vegetables?

Straw mulch?

The straw mulch paradox

Maria's study

- Four preplant and end-of-season amendments
  - Straw
  - Wood chips
  - Grass clippings
  - Control
- Two tillage depths

- Measuring growth, yield, PMN, active C, respiration

Unamended

Straw

Sawdust

Search for practices that sustain soil health in berries continues . .

- Fumigation may not be beneficial in perennial berries
- Long rotations are desirable
- Certain cover crop rotations are better than others
- Compost amendments help under most, but not all conditions
- Calcium sulfate amendment appears to provide benefits under certain conditions
- Soil compaction may not be too detrimental in the absence of pathogens
- Preemergent herbicides may be more problematic in young plantings than generally thought
- Raised beds almost always improve root health
- Straw mulch may be detrimental if incorporated or overused