Impacts of strobilurin fungicides on yield and soil microbial processes in Minnesota strawberry production

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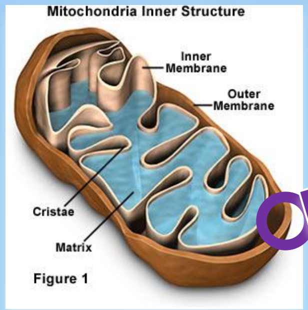
Background – Strobilurin fungicides

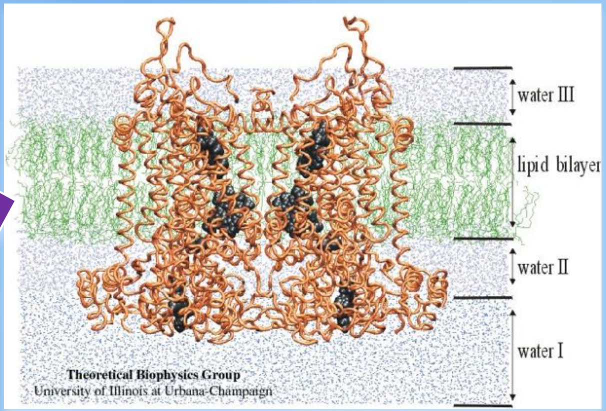
- Many of the newest and most important disease-control chemicals are in the strobilurin class of fungicides
  - In 1991, 10% of global fungicide market
  - Estimates currently well over 65% of global fungicide market

- Initial fungicides were isolated from wood-rotting mushroom fungi (pine cone fungi), including one called ***Strobilurus tenacellus***
  - This is the origin of the name "strobilurin" fungicides

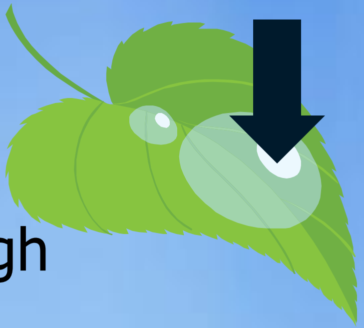
Background (continued)

- Designated: **Q_oI fungicides** (Vincelli, 2002)
  - Interfere with the electron transfer during the energy production of ATP in the fungi mitochondrial cells
  - Targets the electron transfer at the site of quinol oxidation (Q_o site) in the cytochrome BC1 complex
    - Referred to as the Q_oI fungicides based on this mechanism
  - Specific activity → Microbial resistance issues

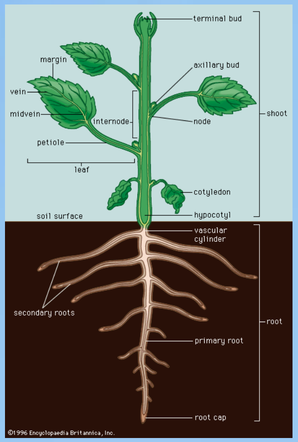




Why are strobilurin fungicides so effective?



1. Q_oI site mode of action
2. **<u>Translaminar movement</u>**
   - "Across the lamina" or chemical can move through the leaf (top to bottom)
   - If sprayed on the top of the leave can be found on the bottom of the leaf



3. Also can move ***<u>Systemically</u>***
   - Through the plant's vascular system
     - leaf → stem →roots

- Leads to several advantages
  - e.g. Compensates for incomplete spray coverage

Increasing Strobilurin (Q_oI) Fungicides Use

- Effective against a wide range of fungal diseases
  - Water molds, downy mildews, powdery mildews, leaf spotting and blighting fungi, fruit rotters, and rusts

- Labeled for use on a variety of crops
  - Berries, carrots, grapes, onions and other bulb vegetables, pome fruit, stone fruit, strawberries, tree nuts, hops, turfgrasses, and ornamentals




Strobilurin Impacts

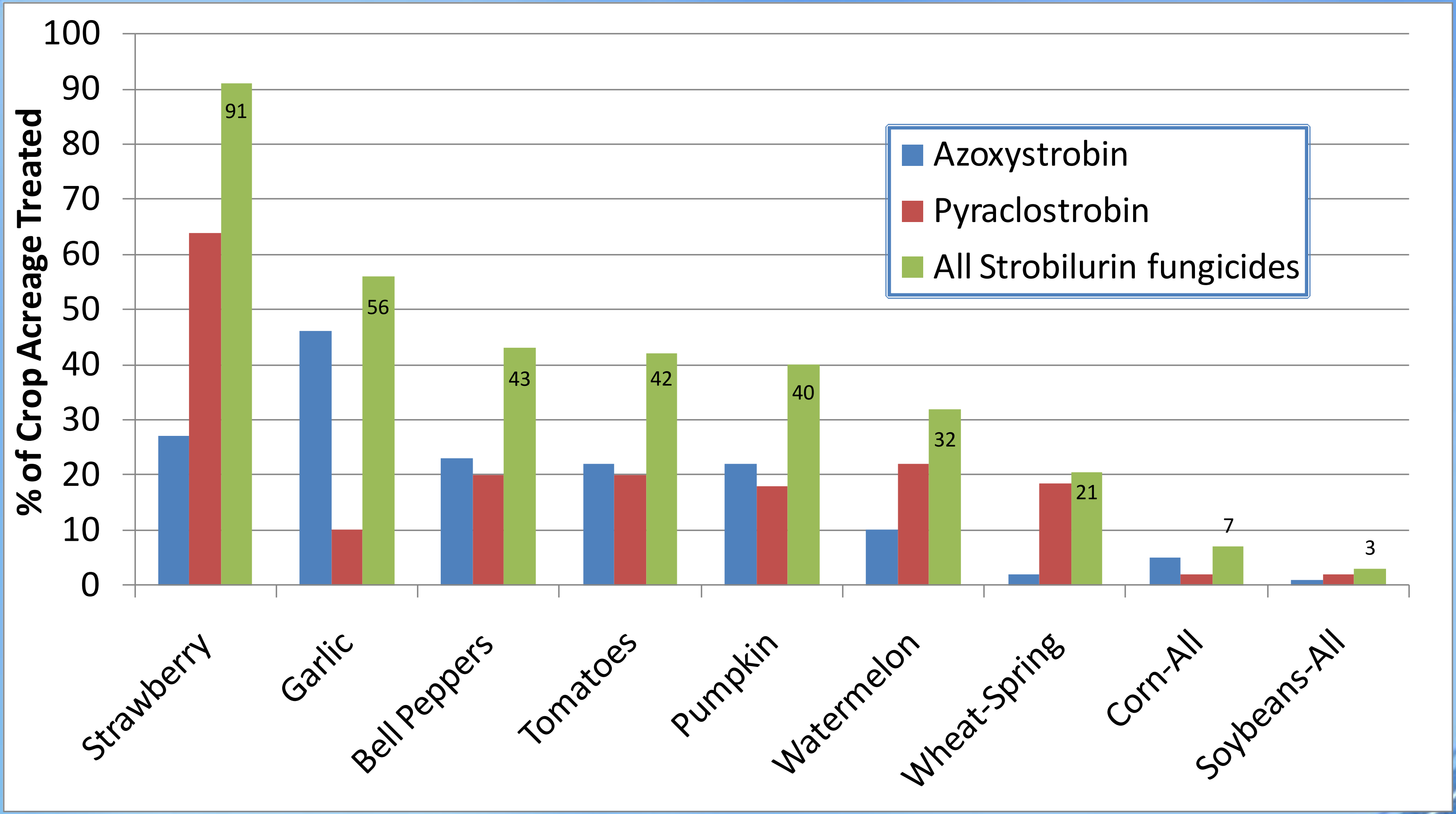
- Several strobilurin (Q_oI) fungicides have been cited to cause <u>positive plant growth and yield</u> effects
- Testimonials of higher yielding "*field trials*"

  - Strobilurin fungicides have been linked to changes in the hormonal balance of wheat
    - Results in increased grain yield, delayed leaf senescence and reduced stomata conductance (water-conserving effects)
  - Claims for other crops

- However, these positive effects are **not** universally observed (e.g. Vincelli and Hershman. 2009)

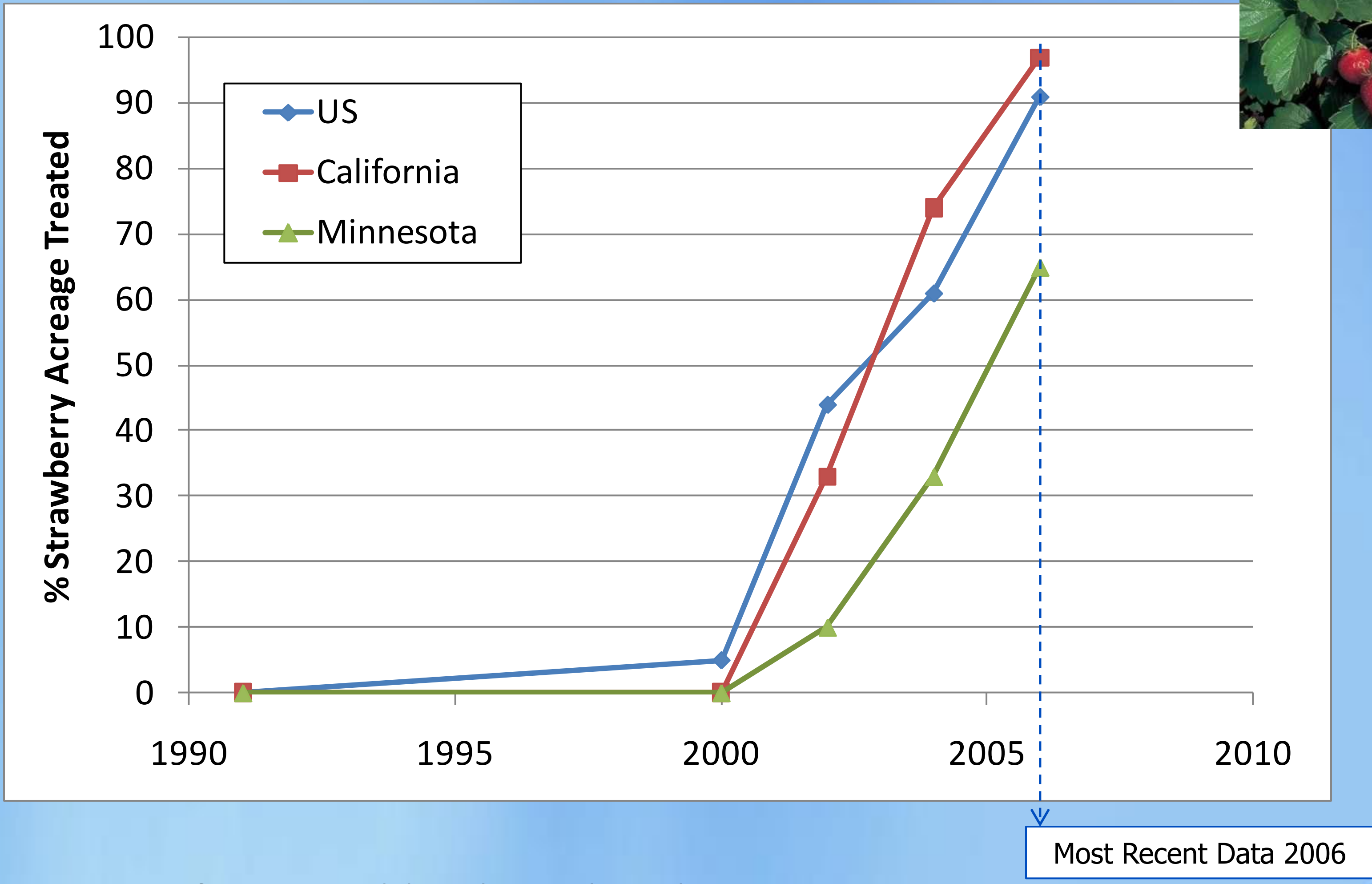
➢ Still influencing the increasing popularity

Strobilurin Use Across Different Commodities (US – 2006 data)



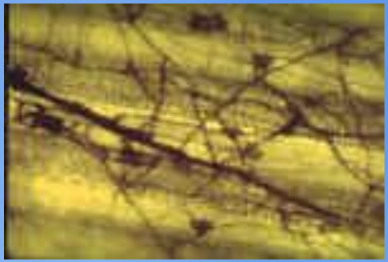
Note: Data from USDA-National Agriculture Statistics Service (NASS) Chemical Use Database located at http://www.pestmanagement.info/nass/

Strobilurin Use in Strawberries



Note: Data from USDA-NASS:|Chemical Use Database and Reports

Importance of fungi



- Fungi have many vital roles
  - Soil water dynamics
    - Physically bind soil particles together (hyphae)
      - increase water infiltration and soil water holding capacity.
  - Nutrient cycling
  - Natural disease suppression
  - Decomposers in the soil food web
    - Particularly for hard-to-digest organic materials
      - cellulose and lignin → crop residues

- Any impact on fungal populations could have large ramifications on the balance of the soil system

Objectives of Current Project

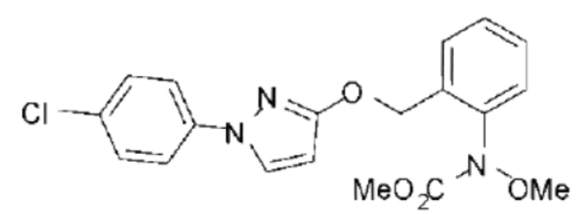
1. Observe impacts on strawberry yield as a consequence of strobilurin use

2. Observe alterations in soil microbial community both in terms of structure and functionality

3. Observe fate and transport of strobilurin fungicide under irrigation
    - Worst case scenario: Sandy soil + irrigation

Fungicide* evaluated

- Pristine® [BASF]#
  - Contains pyraclostrobin



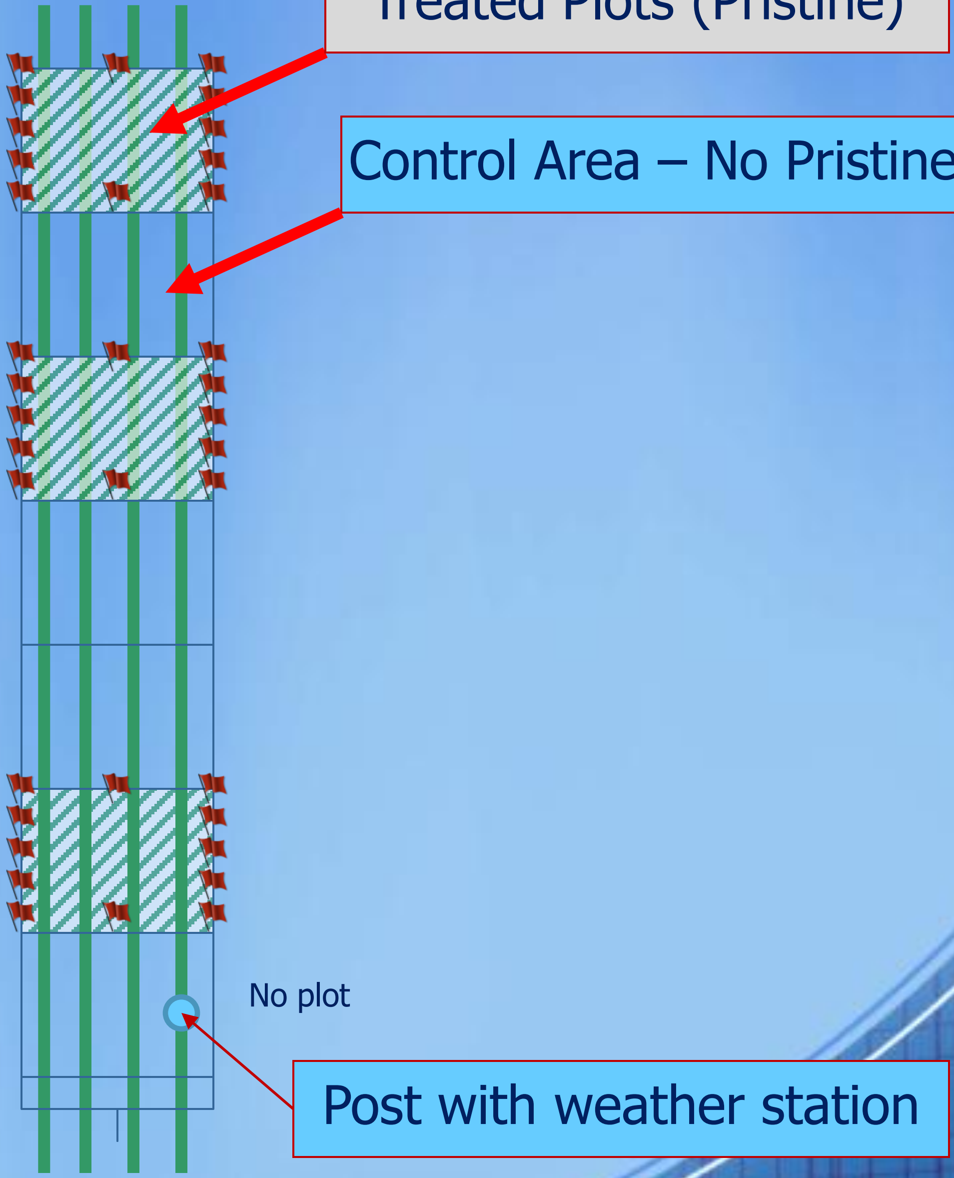
Pyraclostrobin

  - Recall: Over 60% of strawberry production acres apply pyraclostrobin
  - Applied at label recommended rates for strawberry*

- Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable

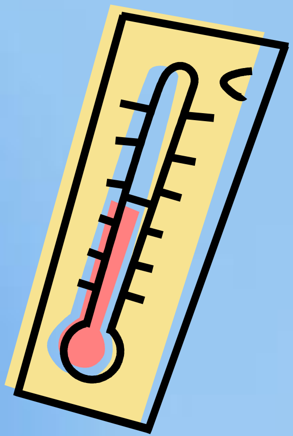
* - This presentation reports research involving fungicides. It does not contain recommendations for their use nor does it imply that uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended

Field Plots



- Triplicate plots (random placement)
- 20 ft x 4 rows of strawberry plants
- Located at edge of field to minimize impacts on management and operations at collaborator field site
- Manual fungicide application with backpack sprayer

Field Data Collected

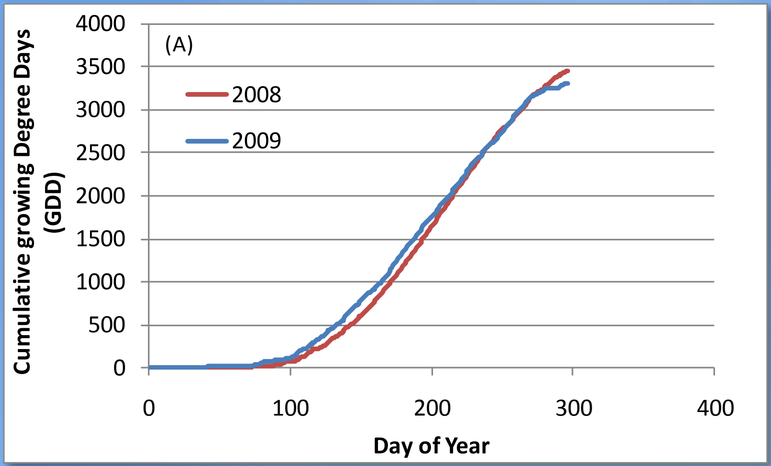


- Continuous weather station
  - Air temperature
  - Precipitation
  - Soil temperature (in-row and between-row)
  - Soil moistures (in-row and between-row)

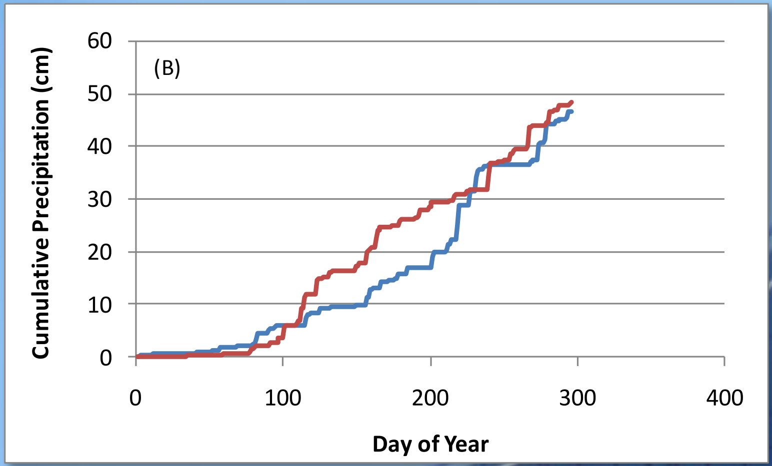
- Soil microbial community profiles
- Greenhouse gas fluxes (bi-weekly)
- 10 cm soil gas concentrations

1. Impacts on Strawberry Yield

- Sampling occurred close to identical growing degree days (GDD)
  - **2008** – June 27
    - 1172 GDD
  - **2009** – June 22
    - 1193 GDD



- Differences in precipitation
  - Not significant due to irrigation

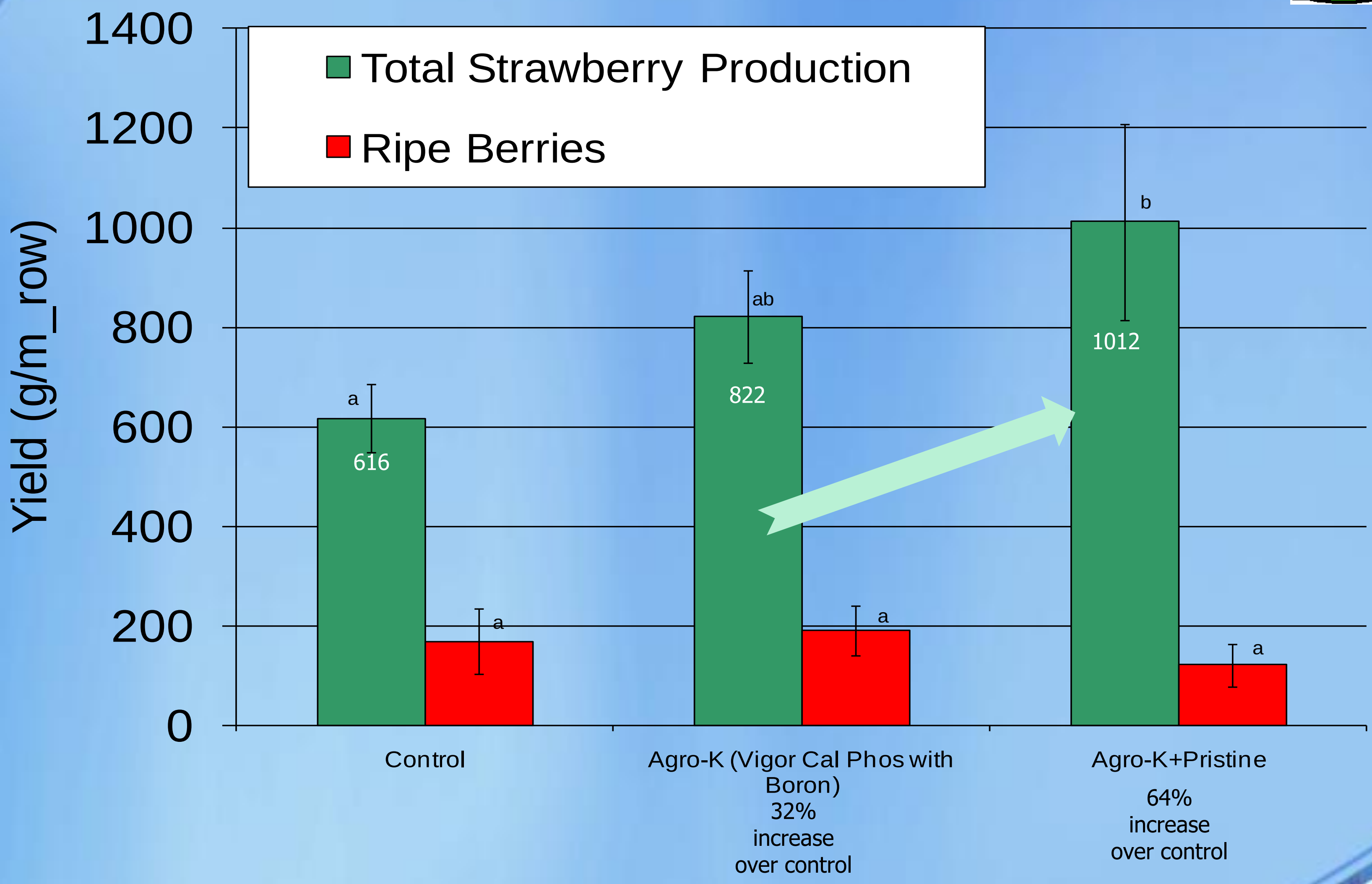


Strawberry Sampling

- Sampling
  - All berries picked in 1 m (3 ft) long row sections
  - 4 sections per plot (randomly selected from 2 middle rows)
  - Excluded 5 ft from plot edge
  - Separated out ripe berries (red) within 1 day of picking
  - Total berries counted and weighed

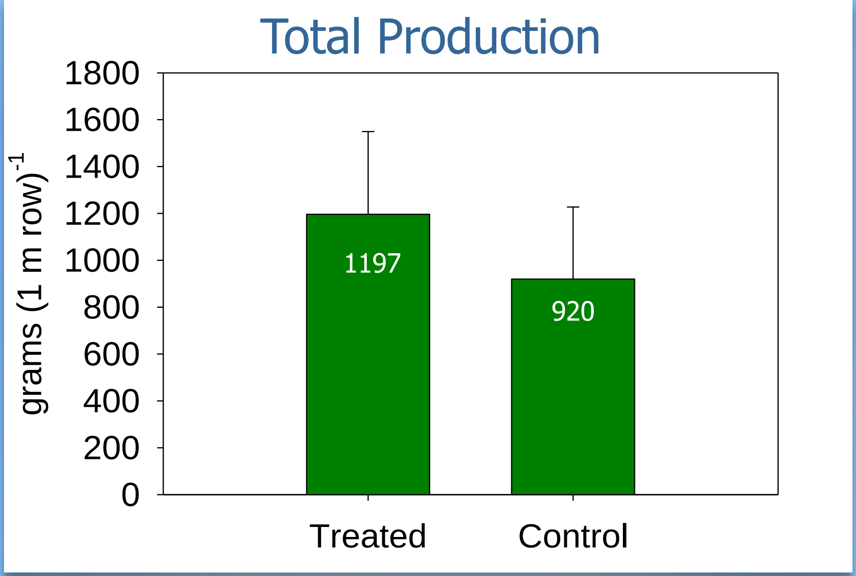
1. Impacts on Yield

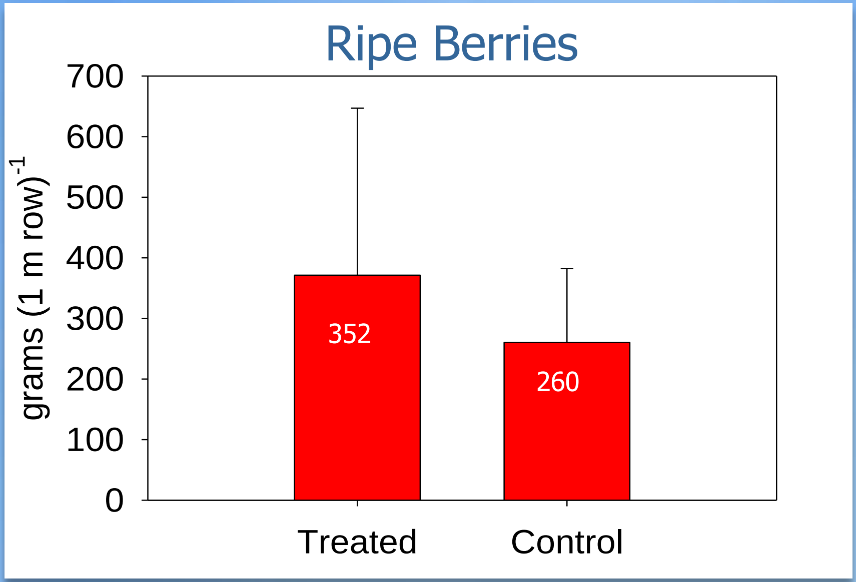
- **June 26, 2008: 1172 GDD**



1. Impacts on Yield

- **June 22, 2009: 1193 GGD**
  - Without fertilizer effect



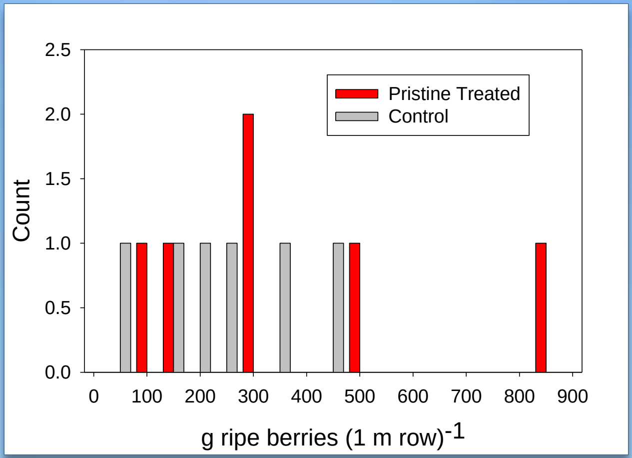


- Although increased production, no statistically significant differences observed

Yield Notes

- No difference observed in individual berry size
  - Control : 8.19 ± 2.3 g/berry
  - Pristine treated : 9.95 ± 3.0 g/berry

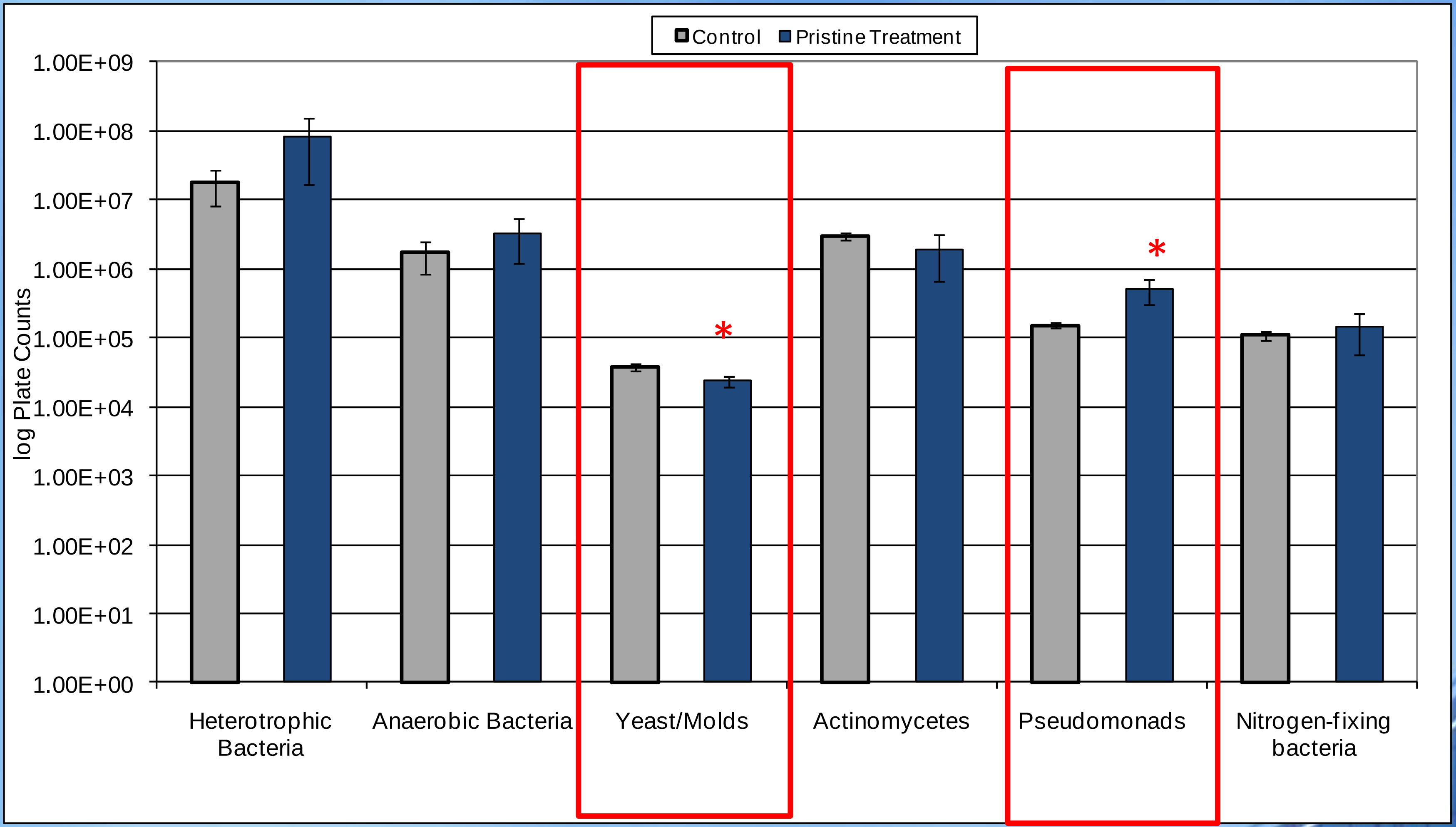
- Highest observed yield of ripe berries in 2009 (887 g/1 m row) was observed in a Pristine treated plot
  However, results for all plots were not statistically different



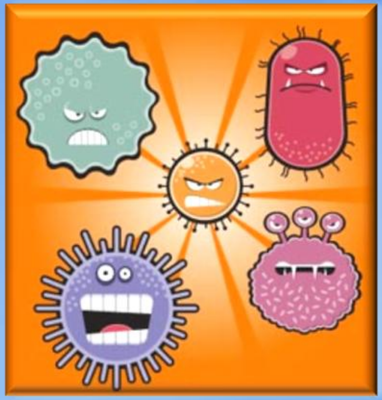
- Stresses the importance of looking at **<u>replicated field plots</u>** as well as **<u>multiple years</u>** of data for fungicide yield effects

2. Impacts on Soil Microbial Community

- Some alterations in the field were seen immediately following Pristine application (surface soil)



2. Impacts on Soil Microbial Community



Summary –

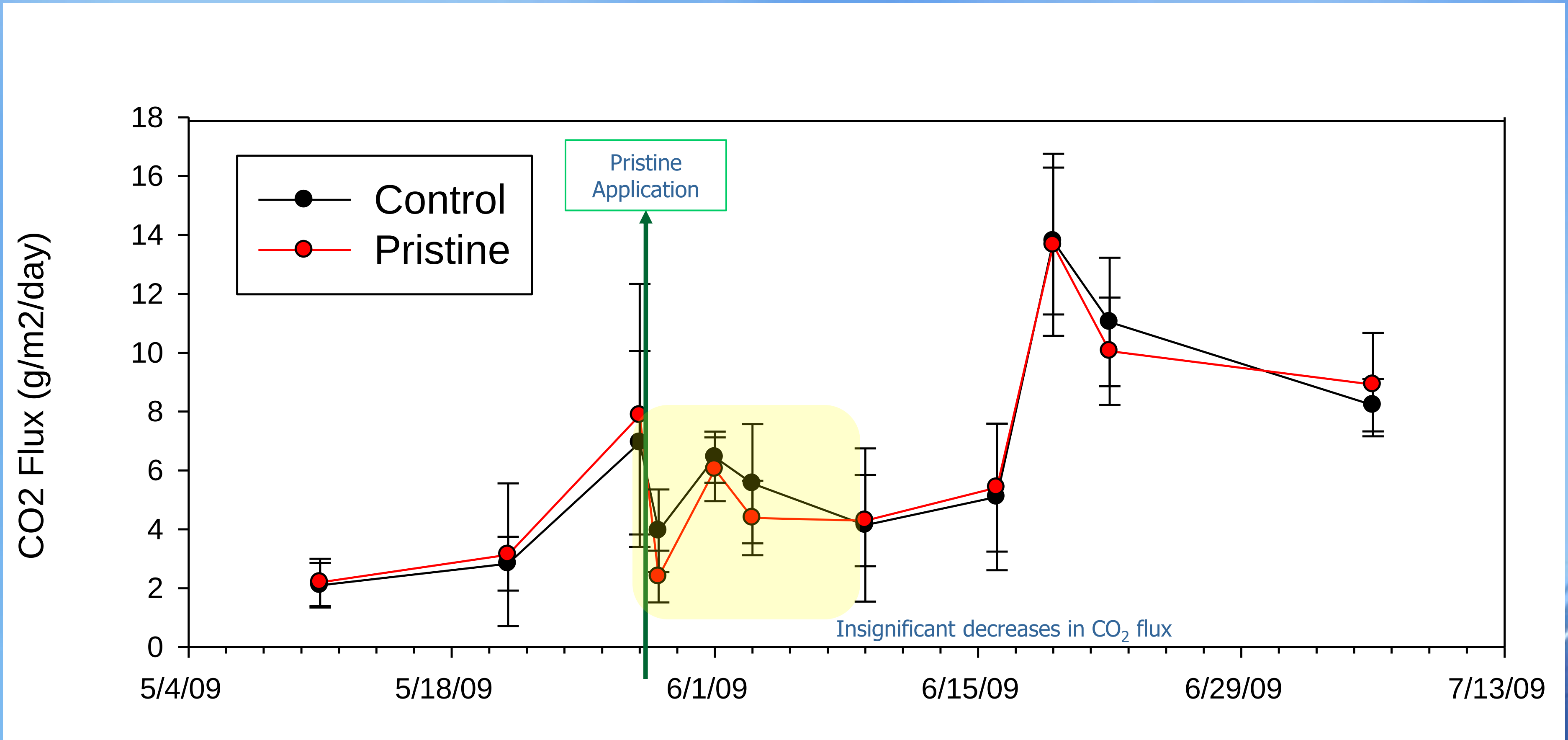
Differences between field and laboratory testing:

- Fungicide decreases **yeasts/molds (fungi)**:
  - **75% reduction** in laboratory incubations
  - **37% reduction** in field plots
- **Pseudomonads** (aerobic gram-negative bacteria)
  - **240% increase** in field sampling
  - No significant increases seen in laboratory incubations
- **Heterotrophic bacteria**
  - No significant differences were observed in the field
  - Laboratory incubations increased heterotrophic bacteria nearly 2-fold (90% increase)

Possible explanation → Field behavior of fungicide

2. Greenhouse Gas Fluxes (functionality)

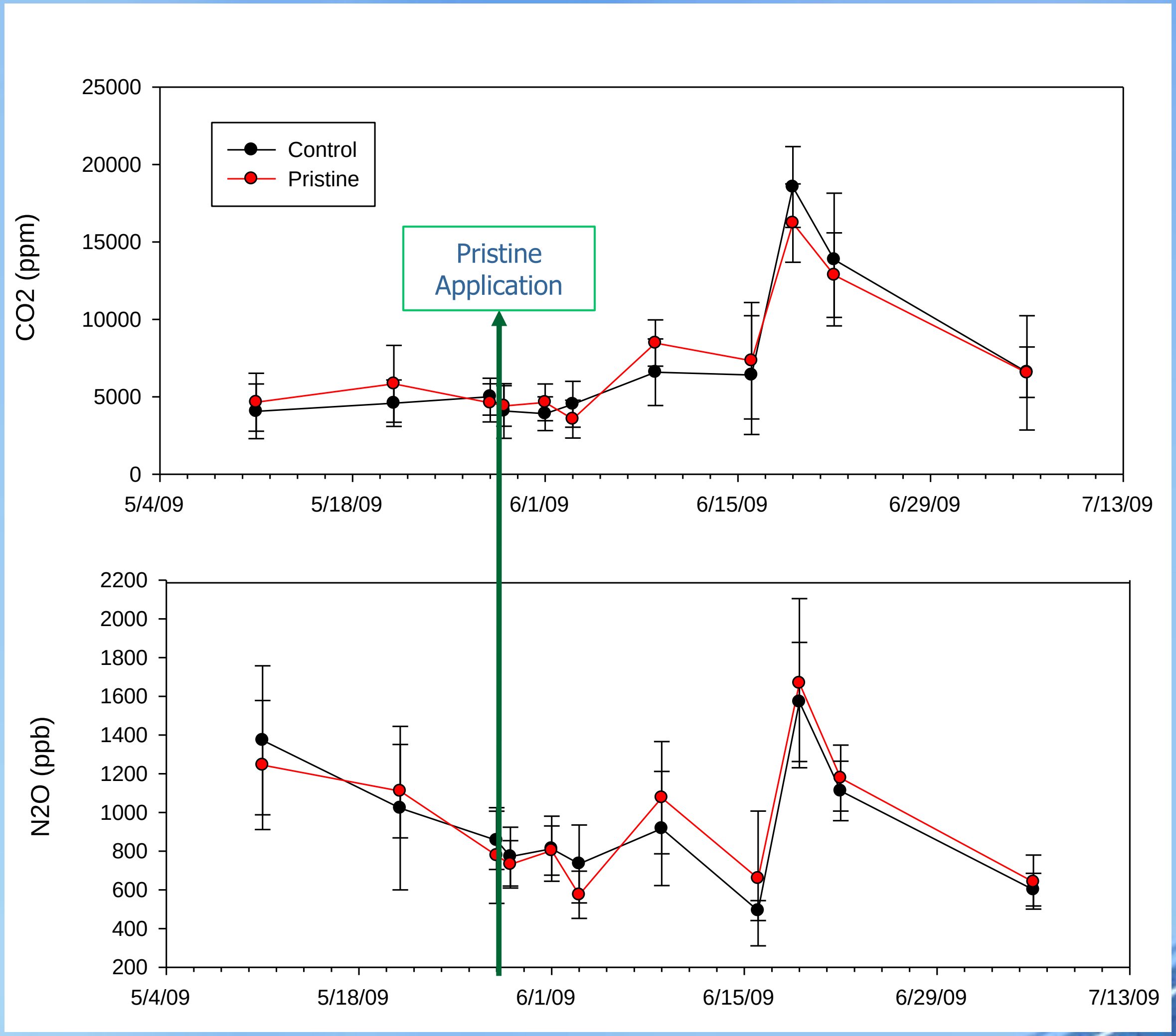
- No differences observed for nitrous oxide (N_2O), carbon dioxide (CO_2) or methane (CH_4) surface flux



- Agrees with microbial sampling results

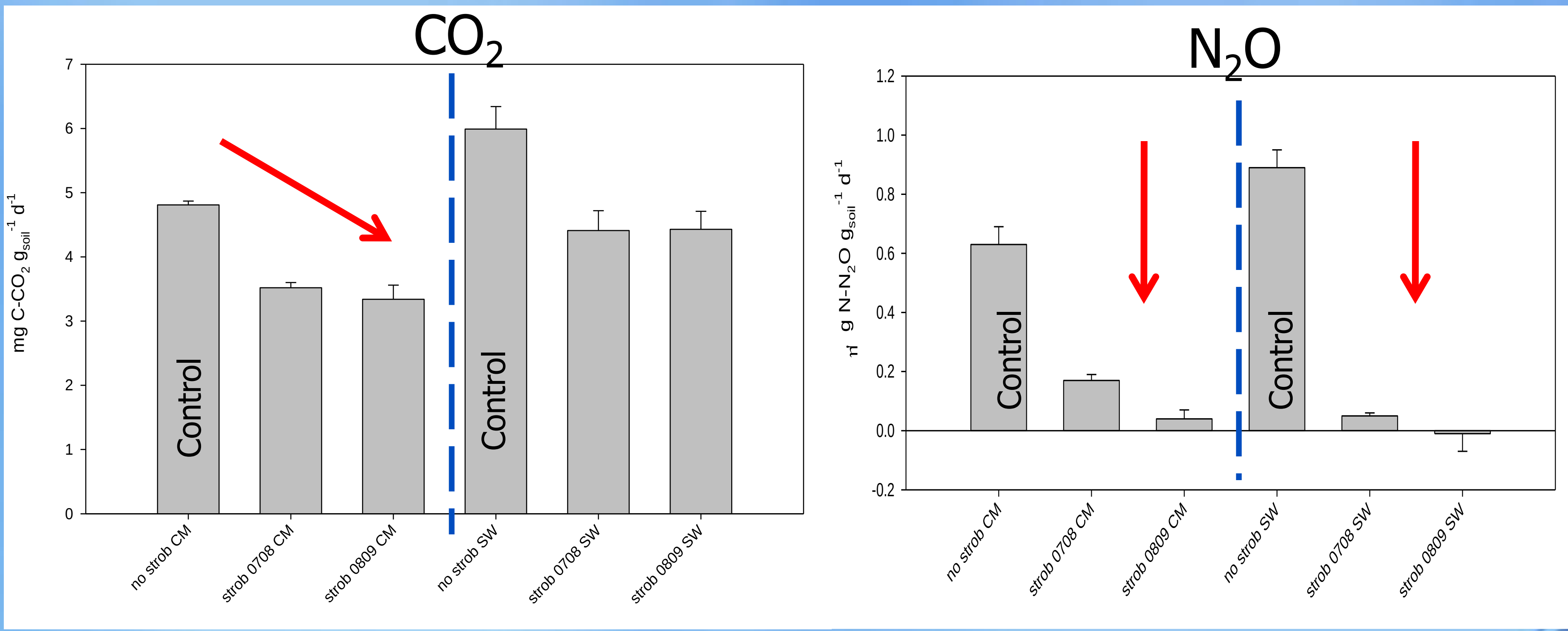
Soil Gas Sampling (10 cm)

- Driving force (concentration gradient) of surface emissions



Contrast to other soil incubations

- Soils with 10+ year history of strobilurin application have also been evaluated in the laboratory



- Strobilurin applications decreased CO_2 and N_2O production

3. Pristine fate and leaching potential

	µg pyraclostrobin per g soil (or straw)	
	2008	2009
	1 day after application	3 days after application
Surface Straw Mulch	1.5	1.0
0-5 cm	<1.0	<1.0
5-10 cm	<1.0	<1.0
10-15 cm	<1.0	<1.0
15-20 cm	<1.0	<1.0
20-25 cm	<1.0	<1.0
25-50 cm	<1.0	<1.0

- Fungicide only detected in straw mulch immediately after application

Strobilurin fate and leaching potential

	µg pyraclostrobin per g soil (or straw)	
	2008	2009
	>7 days after application	>7 days after application
Surface Straw Mulch	<1.0	<1.0
0-5 cm	<1.0	<1.0
5-10 cm	<1.0	<1.0
10-15 cm	<1.0	<1.0
15-20 cm	<1.0	<1.0
20-25 cm	<1.0	<1.0
25-50 cm	<1.0	<1.0

- After 1 week and following → No detection of fungicide in soil or mulch

3. Pristine Leaching

- No leaching observed in the 2 years of field sampling

- Fungicide was not detected in the soil beneath the straw mulch

  - Could explain differences between impacts seen in laboratory soil incubations and field observations

  - Also could explain observed differences between soils from fields with long history (10+ years) of strobilurin use (no mulch present) and soil from current strawberry production

  - Could straw mulch protect the soil from fungicide impacts?

Summary

- Strobilurin use is increasing at exponential rates
  - Particularly high percent use in fruit and vegetable production
- No statistically significant yield increases observed in the first two years of project as a result of fungicide applications
  - Only significant observation: fertilizer + fungicide vs. control(2008)
    - 65% increase in total production
  - All other yields of fungicide to control were not significantly different due to natural variability in the production rates across the field
    - Differences did not exceed those that were expected by chance

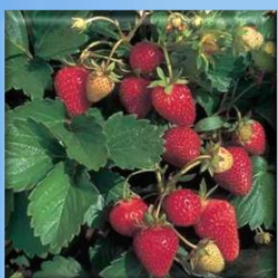
Summary

- Minor alteration seen in field soil microbial community structure
  - Differences did disappear with time
  - Results were different than laboratory incubations
    - No fungicide in the field soil
- No leaching of fungicide was detected into the soil system
  - Strobilurin fungicide only detected in straw mulch immediately after application & dissipated quickly (7 days)
  - Could be one of the reasons for lack of significant microbial impacts
- Current plan is for one more year of monitoring

Acknowledgements

- Bill Jacobson and the entire staff at Pine Tree Apple Orchards for their assistance

Jacobson's PINE TREE APPLE ORCHARD



- Martin du Saire, Tia Phan, Lianne Endo, Lindsey Watson and Matt Montgomery for their assistance with laboratory gas analyses and field sampling

- Brian Barber for his assistance in running the LC-MS analyses of the soil and straw extractions