Active Management of Soil Microbial Communities to Enhance Disease Suppression

Harnessing the Phytobiome to Build Disease-Suppressive Soils – Soil Health Institute Annual Meeting, July 13, 2017

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Phytobiomes

- The entire system of factors that affect or are affected by plants
- Consist of plants, their environment, and their associated communities of organisms
  - Microbial communities
  - Soils
  - Plants
  - Insects, nematodes, other animals
  - Environment
- Understanding phytobiomes important for enabling sustainable and profitable crop production while minimizing negative impacts on the environment

Soil Health and Disease Management

- **Soilborne diseases are most severe when soil conditions are poor**
  - Inadequate drainage, poor structure
  - Low organic matter, fertility
  - High soil compaction
  - Low microbial biomass and diversity

- **Most practices that improve soil health will also reduce soilborne diseases**
  - Improve conditions for crop growth, less disease
  - Increase microbial biomass, activity, & diversity
  - General disease suppression
  - Increase populations of antagonists

- **Specific disease-suppressive practices and strategies for further disease reduction**

Disease-Suppressive Soils

- Soils in which disease does not readily develop despite the presence of the pathogen and susceptible hosts

- Most often result of soil biology – the activity of specific soil microorganisms and/or microbial communities

- Can be induced or developed through changes in soil microbial community characteristics

Management Practices Most Affecting Soil Microorganisms

- **Main Crop Characteristics**
  - Genotype- (cultivar, resistance, exudates, growth)
  - Planting factors (treatment, date, density, etc.)
- **Crop Rotations**
  - Crop type
  - Rotation length
  - Rotation sequence
  - Cover crops
- **Amendments**
  - Organic (manure, compost, residues)
  - Chemical (fertilizer, pesticides)
  - Biological (biocontrol organisms, microbial inoculants)
- **Tillage, Irrigation, Physical factors**

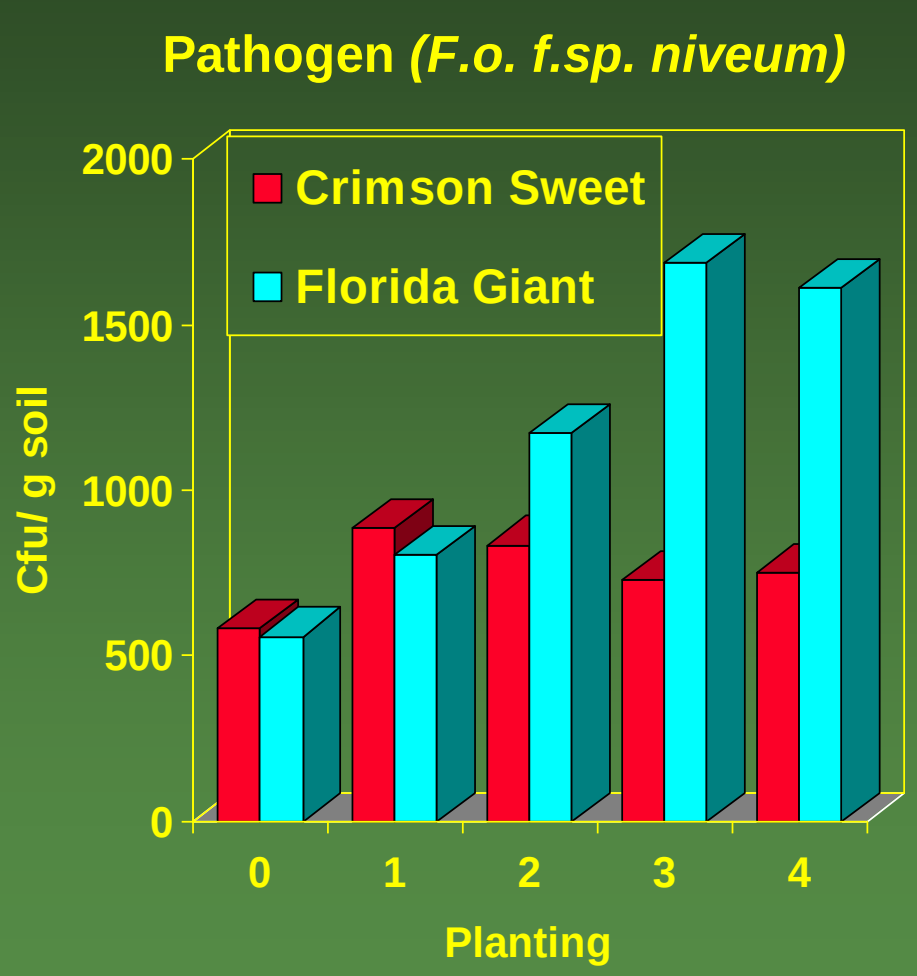
Plants are primary drivers of change in soil microbial communities

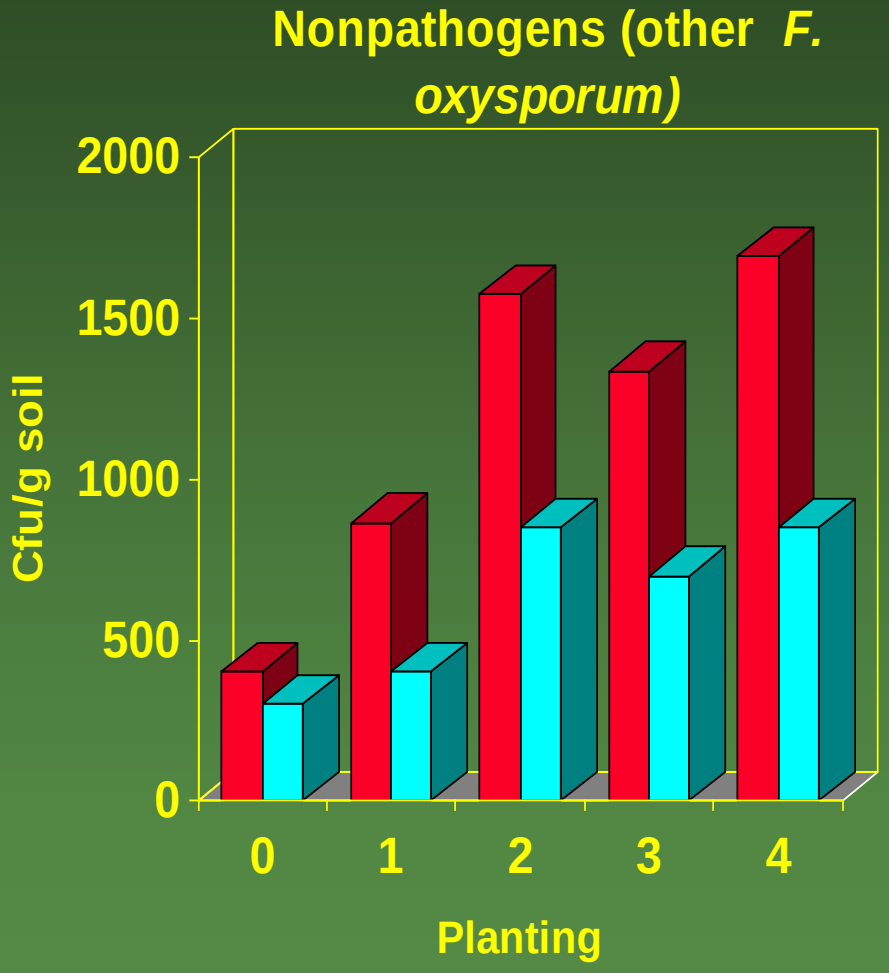
- Microbes respond to abundance and diversity of organic root exudates
- Affects microbial density, activity, structure, composition, and function
- Diversity of plant types, species present yields greater microbial diversity, activity
- Specific plant species, genotypes may select for specific types of microorganisms with varying characteristics
- Use plants to alter, manipulate, manage microbial communities for better crop growth, reduced disease

Limitation: do not yet know enough about specific relationships and interactions among plants and soil microorganisms to fully implement

Crop genotype effects:

Effect of watermelon cultivar on populations of *F. oxysporum*

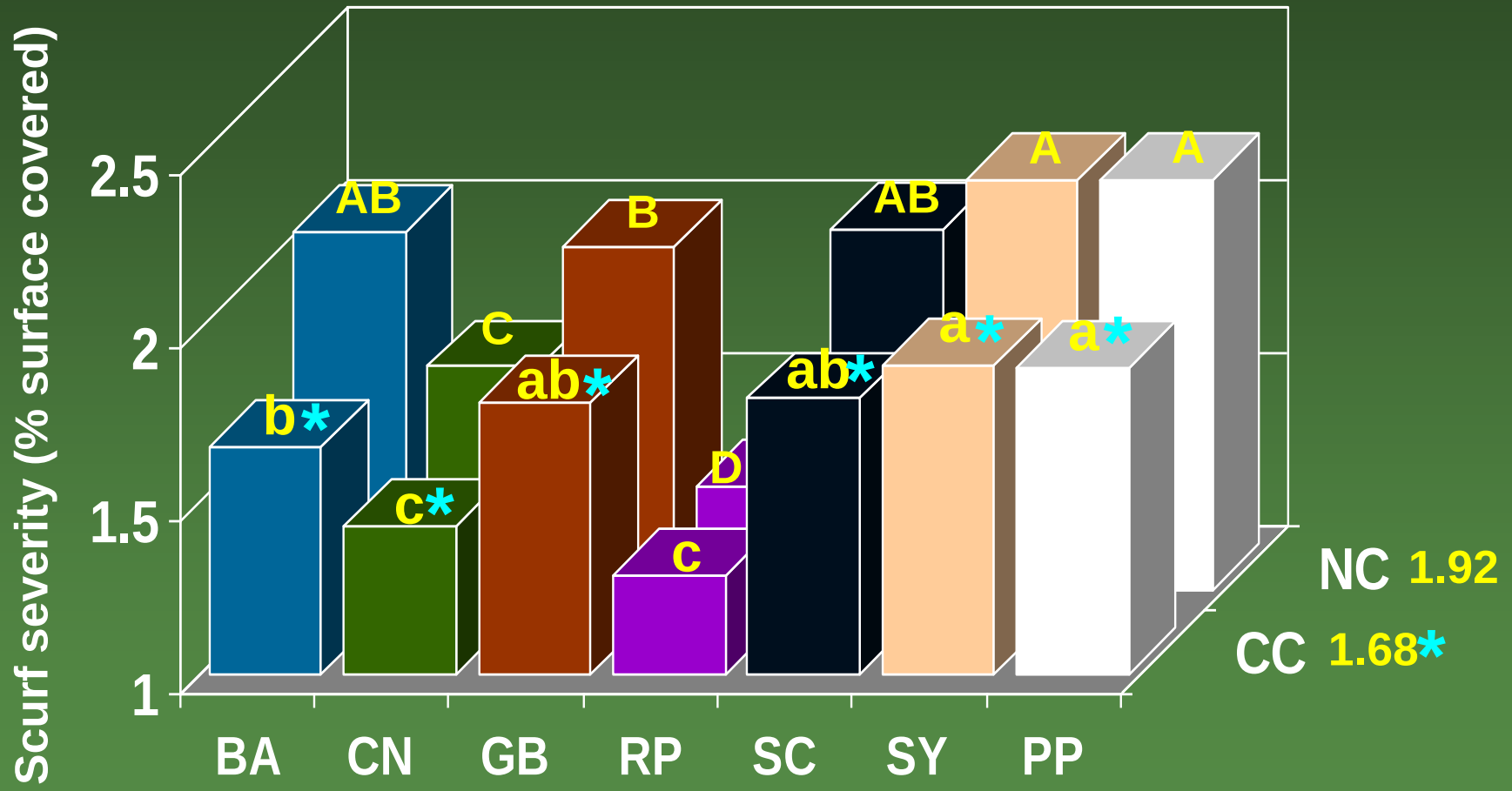




Larkin et al., Phytopathology 83:1097-1104

Cover crop effects:

Effect of rotation crop with and without a cover crop of winter rye on severity of black scurf (3-yr avg).



Larkin et al., 2010. Plant Dis. 94:1491-1502

Disease-suppressive crops

- *Brassica* and related crops

- Sudangrass (Sorghum/sudangrass hybrids)

Disease suppression

- Biofumigation – breakdown produces volatile toxic metabolites
- Changes in Soil Microbial Communities
- Most effective as green manures

Crop Management Strategy Study:

Potato variety: Russet Burbank

3-yr rotations (all entry points) – est. 2004; Presque Isle, ME – continued through 2012

SQ -	**Status Quo (2-yr)**	**Barley (Clover) – Potato**
		Standard rotation
SC -	**Soil Conserving**	**Barley (Timothy) – Timothy**
		Limited tillage, straw mulch
SI -	**Soil Improving**	**Barley (Timothy) – Timothy**
		Plus Compost
DS -	**Disease-Suppressive**	**Mustard GM/rapeseed cover –**
		Sudangrass GM/rye cover
PP -	**Continuous Potato**	**Continuous Potato**

All treatments also implemented under both irrigated (IRR) and non-irrigated (NON) conditions, with irrigation as a split-block factor

Crop Management Strategy Study - Summary:

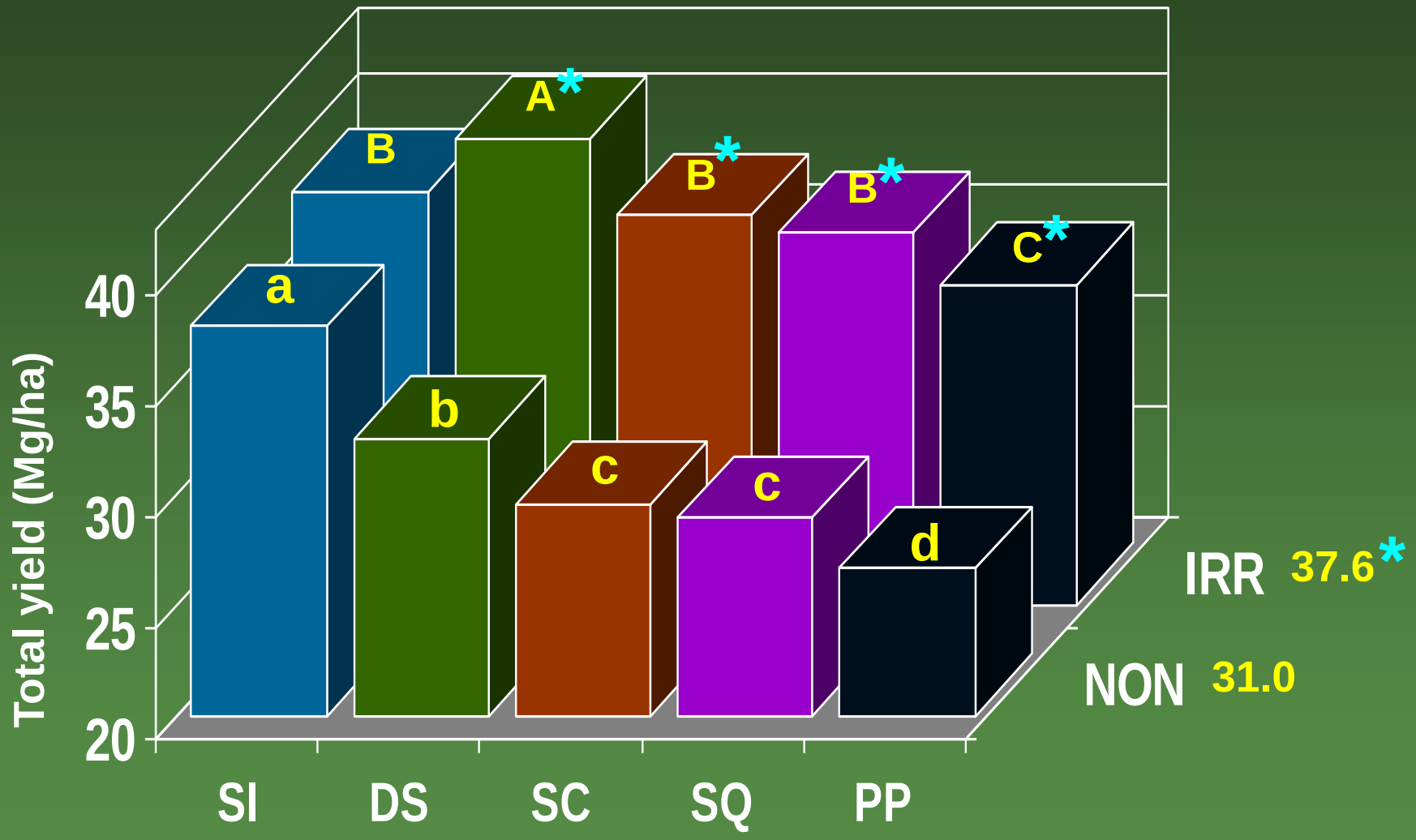
- Cropping system significantly affected soil physical, chemical, and biological properties, as well as tuber yield and disease development, with effects generally becoming more pronounced over time

- All rotations increased aggregate stability, water availability, microbial activity, and yield, and reduced disease relative to no rotation, and 3-yr rotations were superior to 2-yr rotations for several parameters.

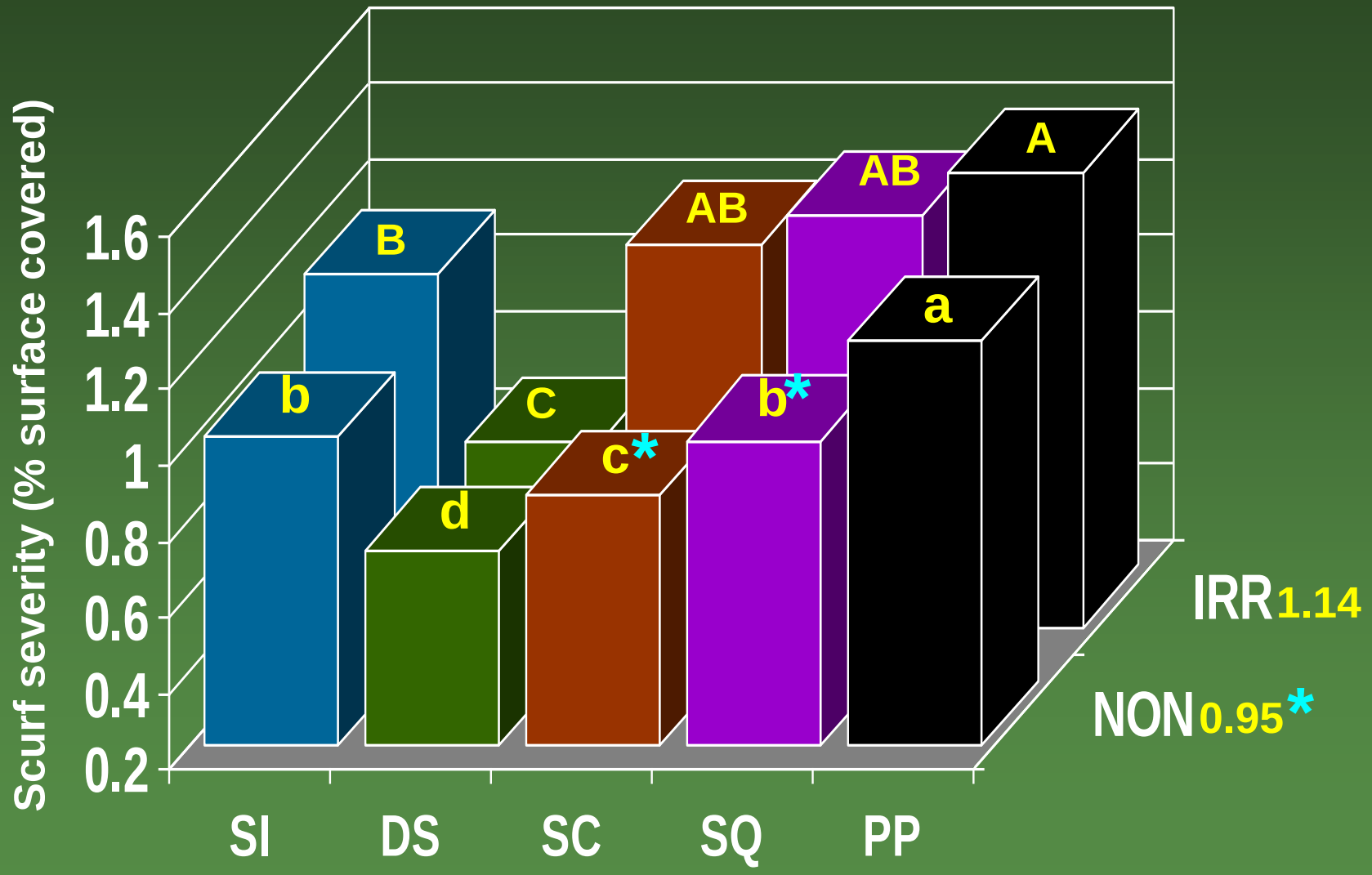
- SI system had the greatest effects on soil health parameters (substantially increasing organic matter and nutrient content, microbial biomass and activity, improving soil structure and water availability) and produced highest yields

- DS system provided more modest improvements in soil health parameters, but high yields and the lowest disease levels of all systems

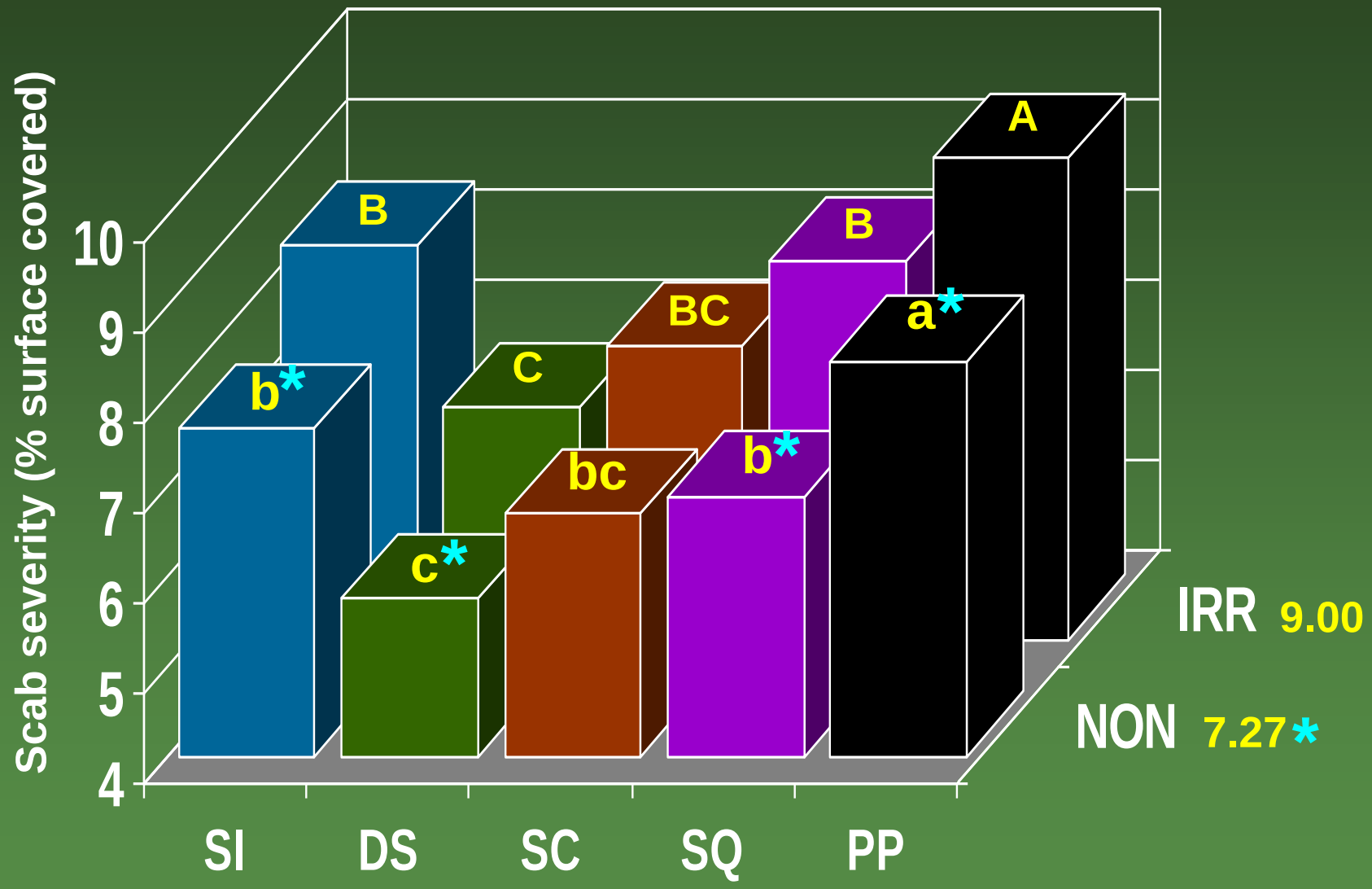
Effect of crop management strategy (3-yr cropping system) with and without irrigation on total tuber yield (5-yr avg).



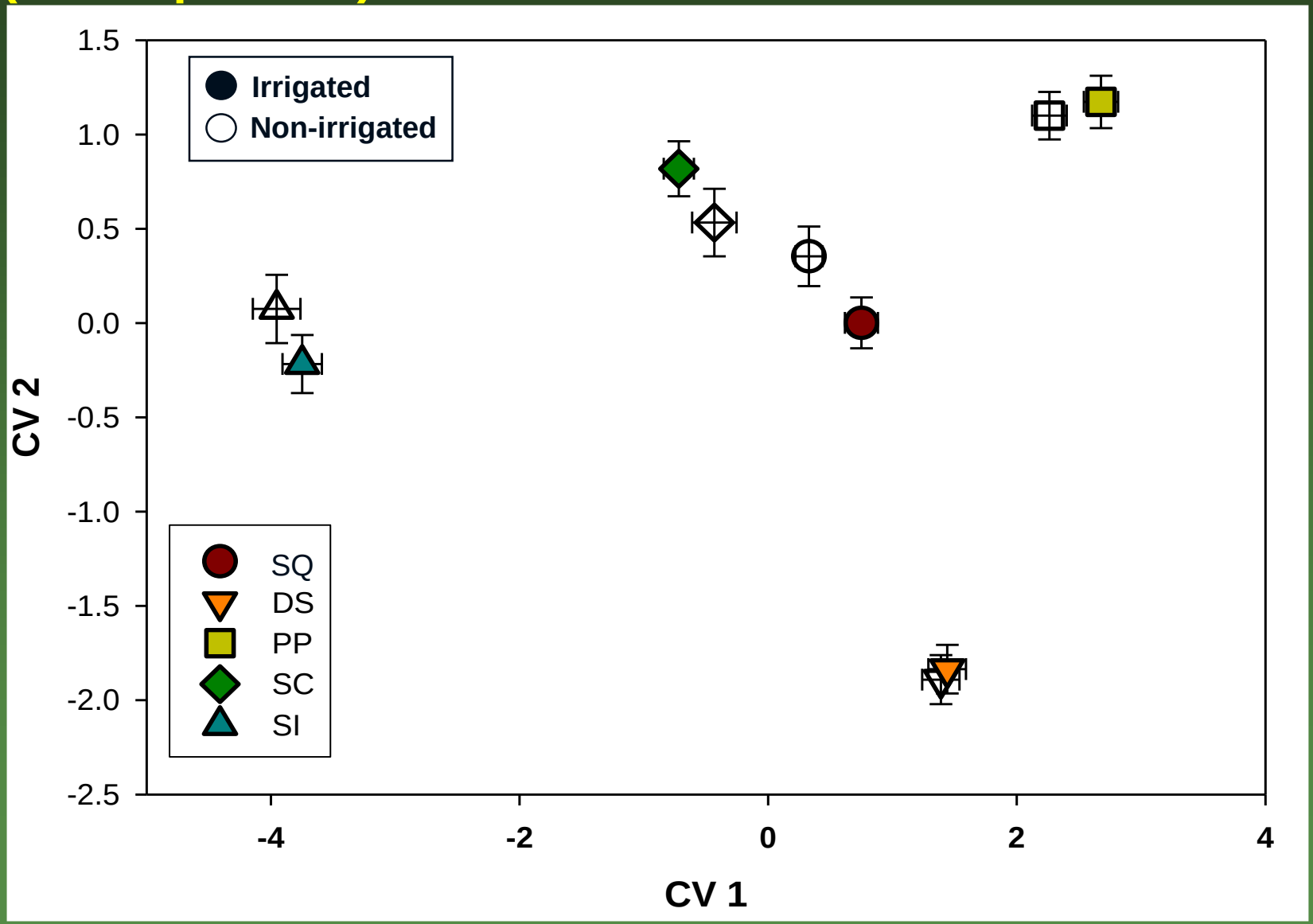
Effect of crop management strategy (3-yr cropping system) with and without irrigation on severity of black scurf (after 6 years)



Effect of crop management strategy with and without irrigation on severity of common scab



Effect of crop management strategy with and without irrigation on soil microbial community characteristics (FAME profiles)



Organic Matter Effects on Soilborne Diseases

- **Overall, increased soil microbial biomass, activity, and diversity from organic matter often results in general or specific forms of disease suppression. However, in practice, results can be quite variable and inconsistent.**

- **In evaluations of a wide range of composts, crops , and pathosystems – (Termorshuizen et al., 2006):**
  - **54% of assays resulted in disease suppression**
  - **43% no effect**
  - **3% increased disease**

- **Another survey of hundreds of studies involving organic amendments – (Bononomi et al., 2007):**
  - **~50%, disease suppression**
  - **~12%, increased disease**

- **Dependent on many factors – compost materials, age, maturity, quality; soil microbiology; soil characteristics; environmental conditions, etc.**

CONCLUSIONS

- Incorporating management practices that promote soil health, such as use of crop rotations, cover crops and green manures, organic amendments, and conservation tillage, into cropping systems can improve soil physical, chemical, and biological properties, resulting in enhanced nutrition, yield, and disease suppression

- Actively growing plants (as main, rotation, and/or cover crops) can be used to affect soil microbial communities to increase microbial biomass, diversity, activity, and antagonism towards pathogens for suppression of plant diseases

- Use of specific plants with disease-suppressive properties can greatly enhance disease reduction and the development of disease-suppressive soils

- Active management of soil microbial communities for enhanced crop productivity and disease suppression is feasible, but more research needed to fully implement

RESEARCH PRIORITIES

- **Better understanding of roles, relationships, effects, interactions of different factors on soil microbial communities, pathogens, and crop production**
  - **effects on microbial communities**
  - **relating specific changes in microbial communities to beneficial, detrimental results**
  - **relevant plant-microbe, microbe-microbe interactions and mechanisms involved**

- **Active management of soil microorganisms for improved disease control, increased plant productivity, and long-term sustainability**
  - **Crop rotations, amendments and other cultural approaches**
  - **Biological manipulations and amendments**
  - **Role of crop genetics (breeding, germplasm)**
  - **Development of pest-suppressive, crop-beneficial microbial environment**

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