

Food, Agriculture, and the Microbiome

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People need safe, plentiful, and nutritious food to eat

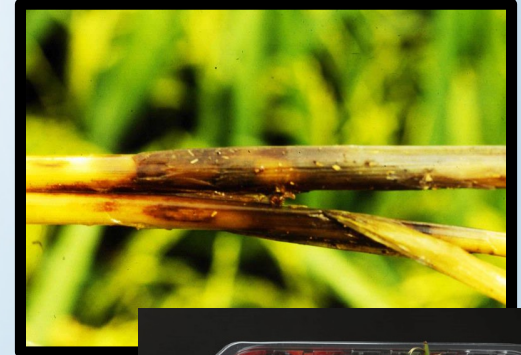


Microbes exist everywhere, and they are important!



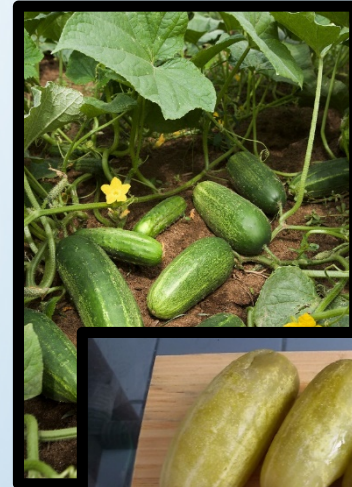
Microbes are a mixed bag...

- Pathogenic microbes cause disease.
- Contaminating microbes can make food unsafe.
- Soil microbes can release greenhouse gases.



Microbes are a mixed bag...

- Beneficial microbes help food grow.
- Probiotics are integral to food safety.
- Soil microbes are important for climate change.



Soil microbes enhance crop immune systems




Biological Control

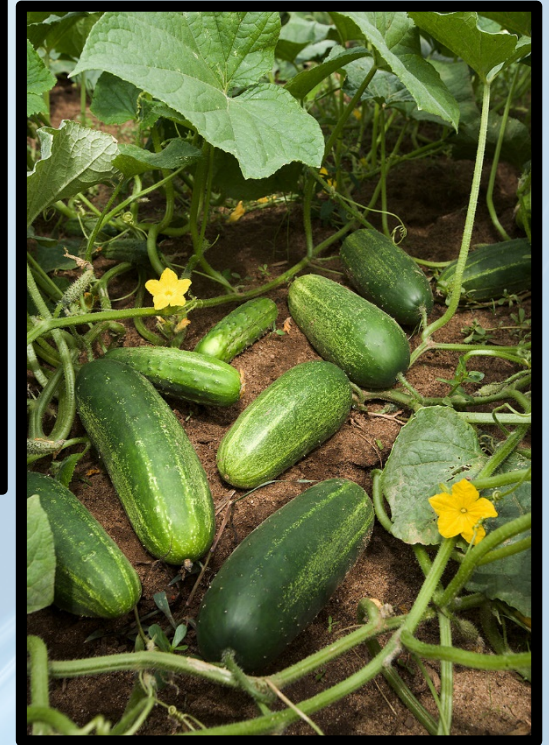
Volume 65, Issue 1, April 2013, Pages 14–23



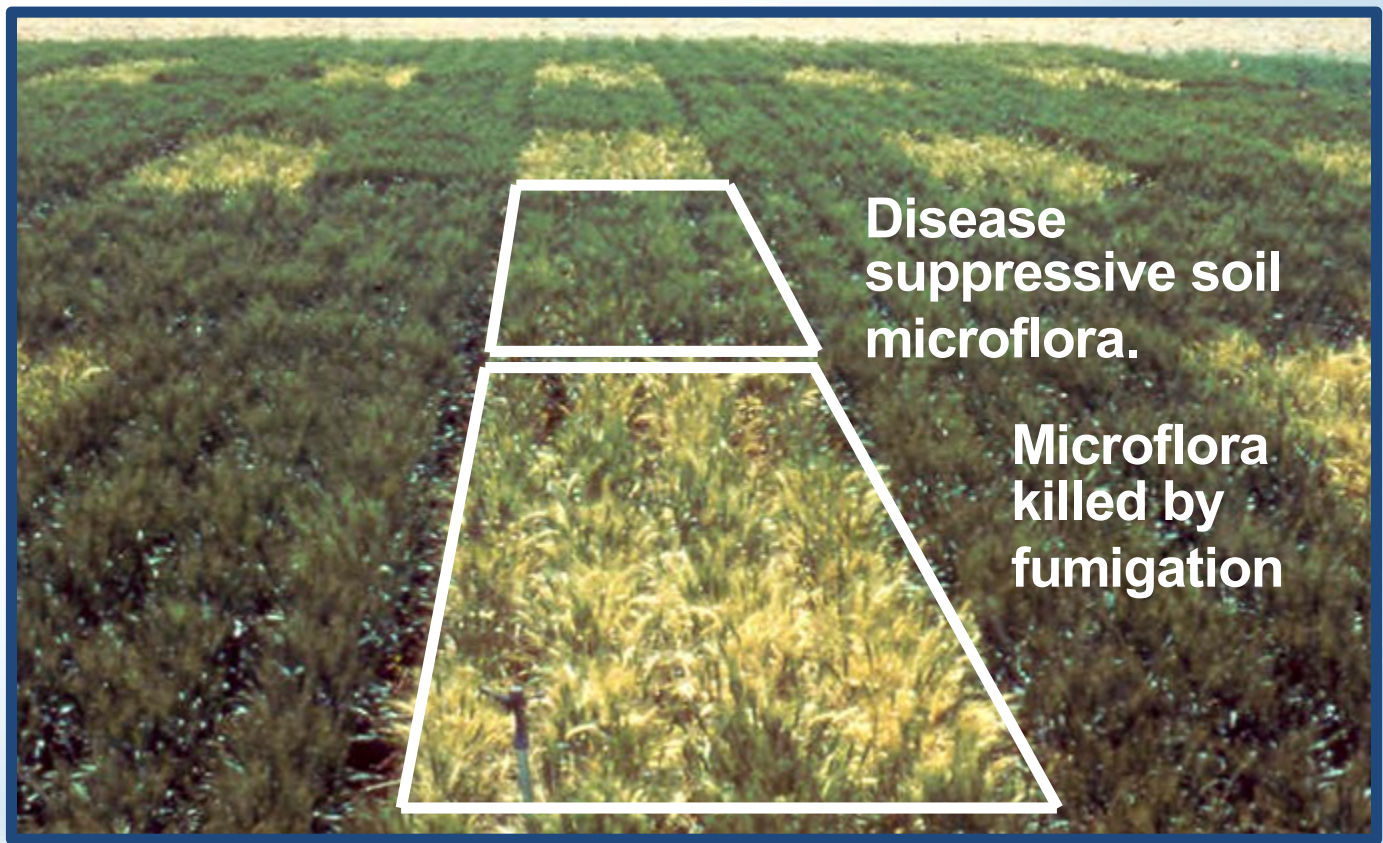
Induced systemic resistance in cucumber and *Arabidopsis thaliana* by the combination of *Trichoderma harzianum* Tr6 and *Pseudomonas* sp. Ps14

Hamidreza Alizadeh^{a, b, c}, Keivan Behboudi^a, Masoud Ahmadzadeh^a, Mohammad Javan-Nikkhah^a,
Christos Zamioudis^b, Corné M.J. Pieterse^b, Peter A.H.M. Bakker^b  

- Fungal and bacterial microorganisms each stimulate the immune systems of cucumber plants.
- Together, their protection against the fungal pathogen, *Fusarium*, enhanced the plants' resistance.



Soil microbes suppress pathogenic fungus



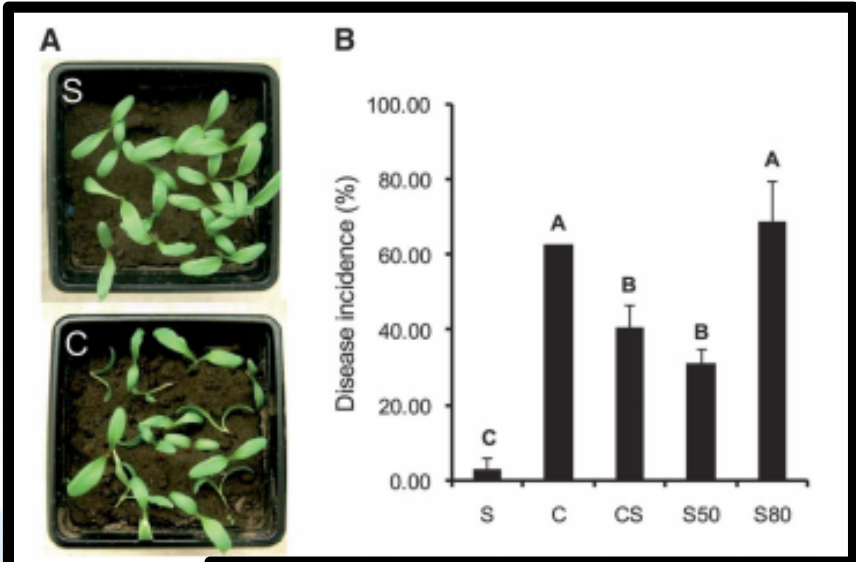
Disease suppressive soil microflora.

Microflora killed by fumigation

Soil microbes suppress pathogenic fungus



Deciphering the Rhizosphere Microbiome for Disease-Suppressive Bacteria
Rodrigo Mendes, *et al.*
Science **332**, 1097 (2011);
DOI: 10.1126/science.1203980



% Disease symptoms of sugar beet seedlings grown in:
S – Suppressive soil.
C – Conducive soil.
CS – Conducive soil with 10% suppressive soil by weight.
S50 – Suppressive soil treated at 50 C.
S80 – Suppressive soil treated at 80 C.

Rhizoctonia solani fungus

Microbes increase crops' nutrient uptake

- Rhizobia, the nitrogen-fixers, are the poster microbes for nutrient uptake.
- Non-symbiotic bacteria can also fix nitrogen and can be used by non-leguminous crops.
- Phosphorus is also a limiting element for plant growth.



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- Non-symbiotic bacteria can also fix nitrogen and can be used by non-leguminous crops.
- Phosphorus is also a limiting element for plant growth.
- Symbiotic mycorrhizal fungi supply phosphorus in exchange for sugars.



Mycorrhizal fungi: The ties that bind
David Read
Nature **388**, 517-518 (7 August 1997)

Microbes increase crops' nutrient uptake



The *In Vitro* Mass-Produced Model Mycorrhizal Fungus, *Rhizophagus irregularis*, Significantly Increases Yields of the Globally Important Food Security Crop Cassava

Isabel Ceballos, Michael Ruiz, Cristhian Fernández, Ricardo Peña, Alia Rodríguez , Ian R. Sanders  


Published: August 7, 2013 • <http://dx.doi.org/10.1371/journal.pone.0070633>

- Cassava plants are never non-mycorrhizal in the field (plants grown in sterile soil are 10-20 times smaller).
- Different mycorrhizal fungi species have variable effects on cassava growth.
- *In vitro*-produced *Rhizophagus irregularis* tested on two cassava fields in Colombia was found to effectively increase yields at both sites in an economically viable manner.

Microbes partner with crops in extreme environments



Increased Fitness of Rice Plants to Abiotic Stress Via Habitat Adapted Symbiosis: A Strategy for Mitigating Impacts of Climate Change

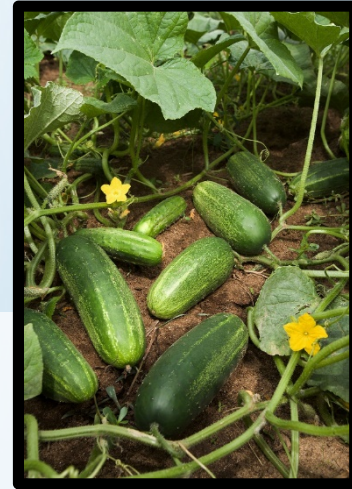
Regina S. Redman , Yong Ok Kim, Claire J. D. A. Woodward, Chris Greer, Luis Espino, Sharon L. Doty, Rusty J. Rodriguez

Published: July 5, 2011 • <http://dx.doi.org/10.1371/journal.pone.0014823>

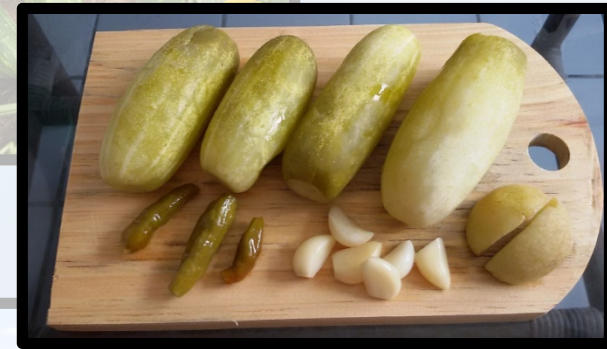
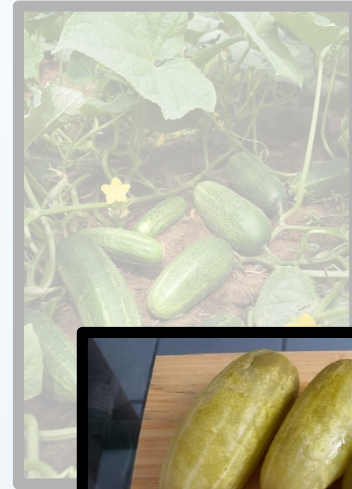
- Collected endophytic fungi from coastal dune grass (salt adapted), and panic grass (heat adapted).
- Commercial rice plants not adapted to salt, drought, heat, or cold stress were inoculated.
- The inoculated rice used less water and set more seeds than the control when exposed to salt, drought, or cold (5-20 C).



- Beneficial microbes help food grow.
- Microbes are integral to food safety
- Soil microbes are important for climate change



- Beneficial microbes help food grow.
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Microbes are integral to food safety

- Outbreaks are notoriously difficult to predict.
 - The worst outbreaks in the past twenty years have been in: green onions, spinach, peanut butter, cantaloupe, and cucumbers.
 - This year, 172 people across 32 states got sick from eating romaine lettuce, and one person died.



Microbiome research to improve food safety.

“Consortium for Sequencing the Food Supply Chain”

- Run by IBM and Mars, Inc.
- Sequence the global food chain:
 - Farms, transportation, processing facilities, and distributors.
 - Restaurants and grocery stores.
- Gather data
- Create a baseline from which to monitor changes
- Stop outbreaks before they start

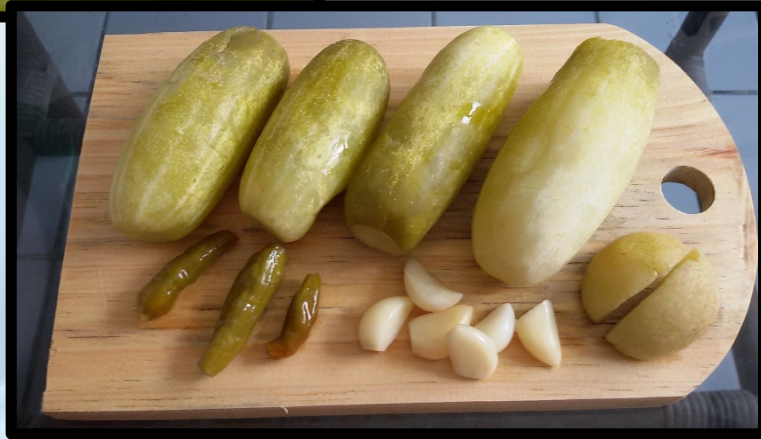
Beneficial microbes keep foods safe and people healthy



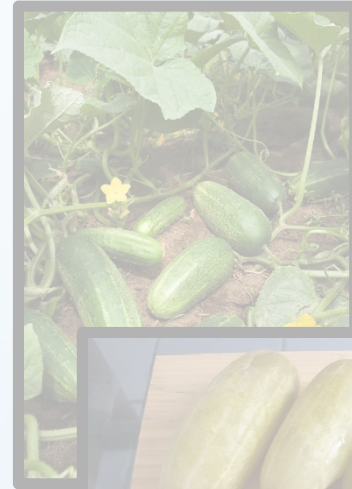
How do probiotics or probiotic-rich foods affect the human gut microbiome?



What other organisms or nutrients are beneficial?



- Beneficial microbes help food grow.
- Microbes are integral to food safety.
- Soil microbes are important for climate change.



Modern farming releases greenhouse gases

- Soil microbes represent more than 30% of the GHGs released in farming.
 - Tillage exposes soil microbes.



Effects of No-Till on Yields as Influenced by Crop and Environmental Factors

Dustin K. Toliver,* James A. Larson, Roland K. Roberts, Burton C. English, Daniel G. De La Torre Ugarte, and Tristram O. West

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Environmental Science Societies DIGITAL LIBRARY

Modern farming releases greenhouse gases

- Soil microbes represent more than 30% of the GHGs released in farming.
 - Tillage exposes soil microbes.
 - A decrease in crop residue can lead to increases in greenhouse gas emissions and reduced microbial communities.



Soil & Water Management & Conservation

Greenhouse Gas Emissions Dynamics as Influenced by
Corn Residue Removal in Continuous Corn System

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Modern farming releases greenhouse gases

- Soil microbes represent more than 30% of the GHGs released in farming.
 - Tillage exposes soil microbes.
 - A decrease in crop residue can lead to increases in greenhouse gas emissions.
 - Soil microbes in flooded rice paddies release methane gas.
 - Manure can run-off or increase nitrous oxide emissions from the soil.



Agricultural management can sequester carbon

- Researchers are investigating management practices that increase soil organic carbon.
 - No-till
 - Residue retention
 - Crop rotation
 - Planting varieties with deep roots



Summary

- Microbes are everywhere, and they are important
- Beneficial microbes help food grow
- Probiotics are integral to food safety
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