Towards Integrated Soil Health Management:
A perspective from soilborne disease management in strawberries

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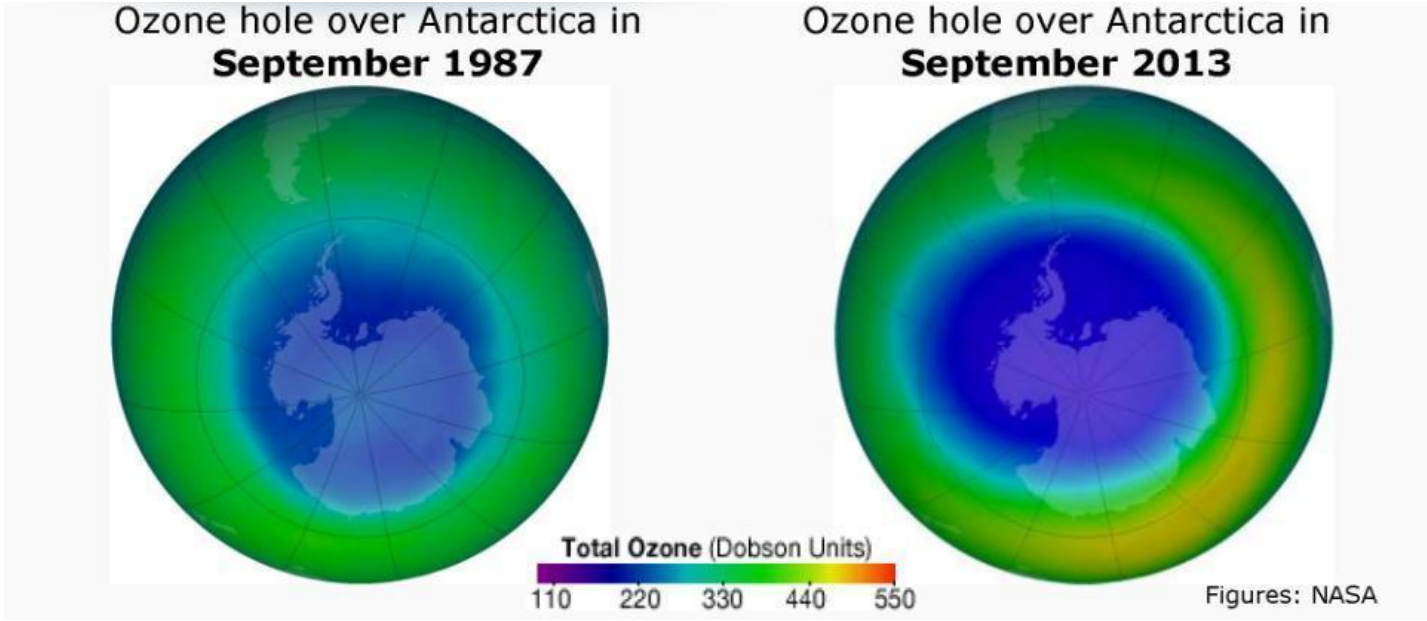
Outline

1. Soilborne disease management by fumigants in California conventional strawberries
2. Integrated soilborne disease management (ISDM) in California organic strawberries
3. Integrated soil health management (ISHM)
   - A vision for the next 10 years

Chemical fumigation

- Methyl bromide + chloropicrin
- Control soilborne disease and weeds, increase yield
- Core technology for the large-scale high yielding mono-cultural strawberry production for the last 50 years

Ozone Hole and Montreal Protocol



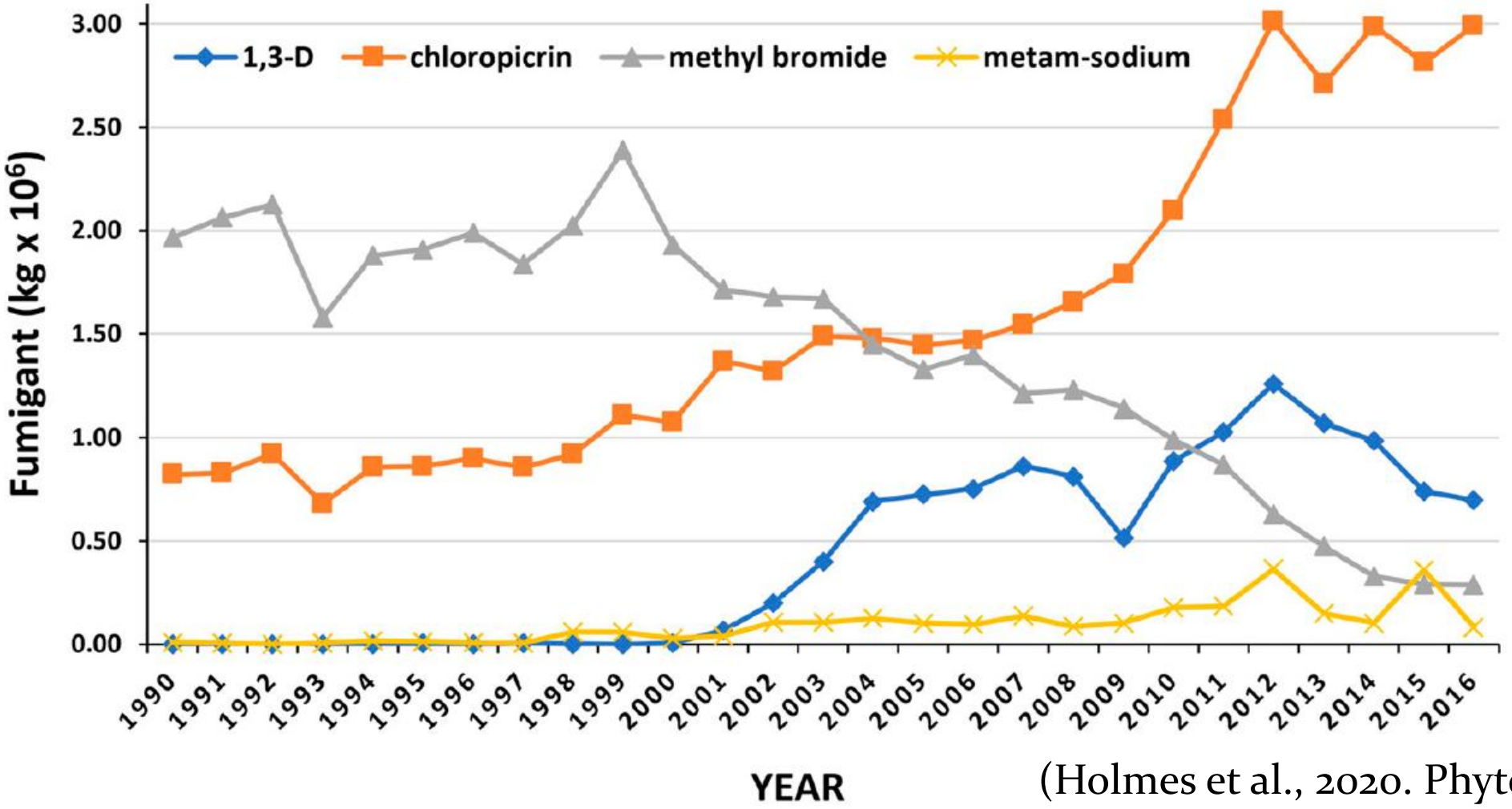
- Ozone layer: Earth's "sun screen" – protects people, plants, and animals from ultraviolet radiation
- Skin cancer is the most common cancer in the US

→ 1992: Methyl Bromide added to Montreal Protocol

→ 2005: 100% phase out with limited exemptions in developed countries

→ 2016: Critical Use Exemption in CA expired

Four major soil fumigants used at strawberry fields in California from 1990 to 2016



(Holmes et al., 2020. Phytopathology)

- Since 2003, DPR has documented **<u>hundreds of acute illnesses</u>** caused by accidental fumigant exposure to agricultural workers as well as people living near fumigated fields

-> Regulation of fumigants becoming increasingly stringent

-> Future of fumigants availability is uncertain

-> Important to study alternatives proactively while we still have fumigants *(USDA-SCRI project: Developing non-fumigant approaches in strawberry production in CA, FL, NC, TN, and WA)*

Integrated soilborne Disease Management (ISDM) for California Organic Strawberries

ISDM

Soilborne pathogen diagnosis (or disease history)

Cultural/Molecular-base test

- *Verticillium dahliae*
- *Fusarium oxysporum* f. sp. *fragariae*
- *Macrophomina phaseolina*

Selecting/integrating strategies

- Crop rotation
- Resistant variety
- Anaerobic soil disinfestation (ASD. C-source options), steam
- Sanitation (washing tools, tractors)
- (Fumigation)

Soilborne Pathogen Diagnostics using Molecular Approaches

- Fast and accurate!
  (1 day vs. 1 month by Cultural method)

Molecular approach	*V. dahliae*	*F. oxysporum* f. sp. *fragariae*	*M. phaseolina*
Plant test	○	○	○
Soil test	○	○ NEW!	○
Soil test economic threshold	○	X	X

Crop Rotation for Strawberry

- Traditional method to avoid soilborne diseases in strawberries worldwide
  - Mandatory for organic strawberry production under the National Organic Program
  - Minimum of a 3-year break between two strawberry plantings recommended in EU and Northeast US and Canada
  - Anecdotal local evidence: at least 2-year break to avoid Fusarium wilt (longer for highly infested sites)
  - Including suppressive crops (broccoli for Verticillium wilt, allium for Fusarium wilt?, wheat Summit 515 for Macrophomina?)

Anaerobic Soil Disinfestation (ASD)

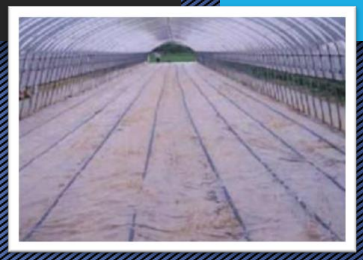
- Developed in the Netherlands and Japan independently ~2000 as a biological alternative to fumigation
- Principle: Acid fermentation in anaerobic soil

1. Broadcast rice bran at <u>6 - 9 tons/acre</u>
2. Incorporate bran
3. List beds
4. Cover w/ plastic mulch
5. Drip irrigate total 1 to 2 ac-in over 3 wks
6. Leave 3 wks and **<u>monitor soil Eh (redox potential)</u>**

ASD controls
- Verticillium wilt by autumn treatment
- Fusarium wilt by summer treatment

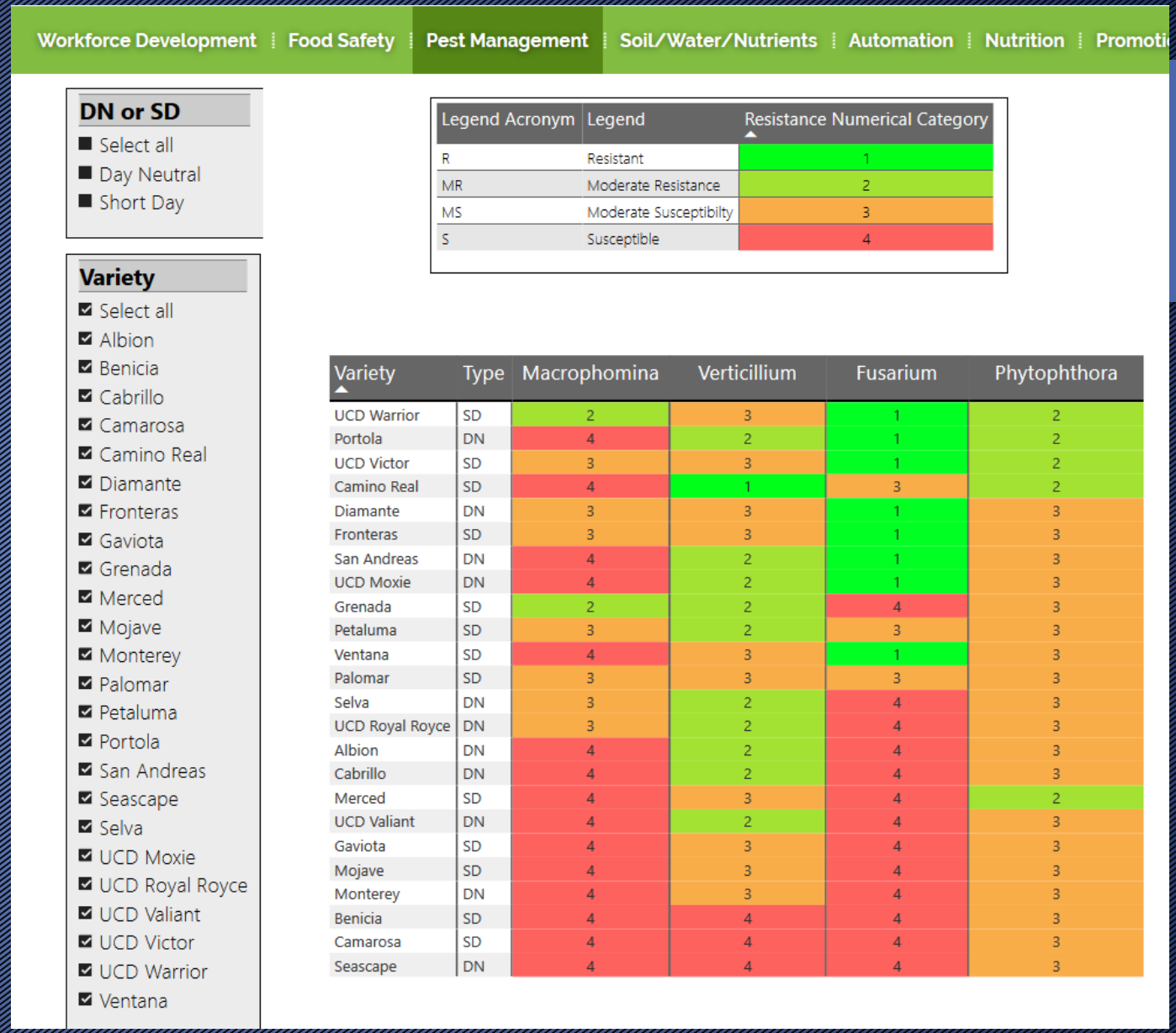
Don't use autumn ASD in Fusarium-infested sites!

(Van Bruggen, 2014)


(Chiba prefecture, 2002)

Resistant Varieties

- Most practical and reliable approach
- No single variety that is resistant to all 3 pathogens
- No strong Macrophomina charcoal rot resistant variety
- No good Fusarium wilt resistant variety with excellent flavor

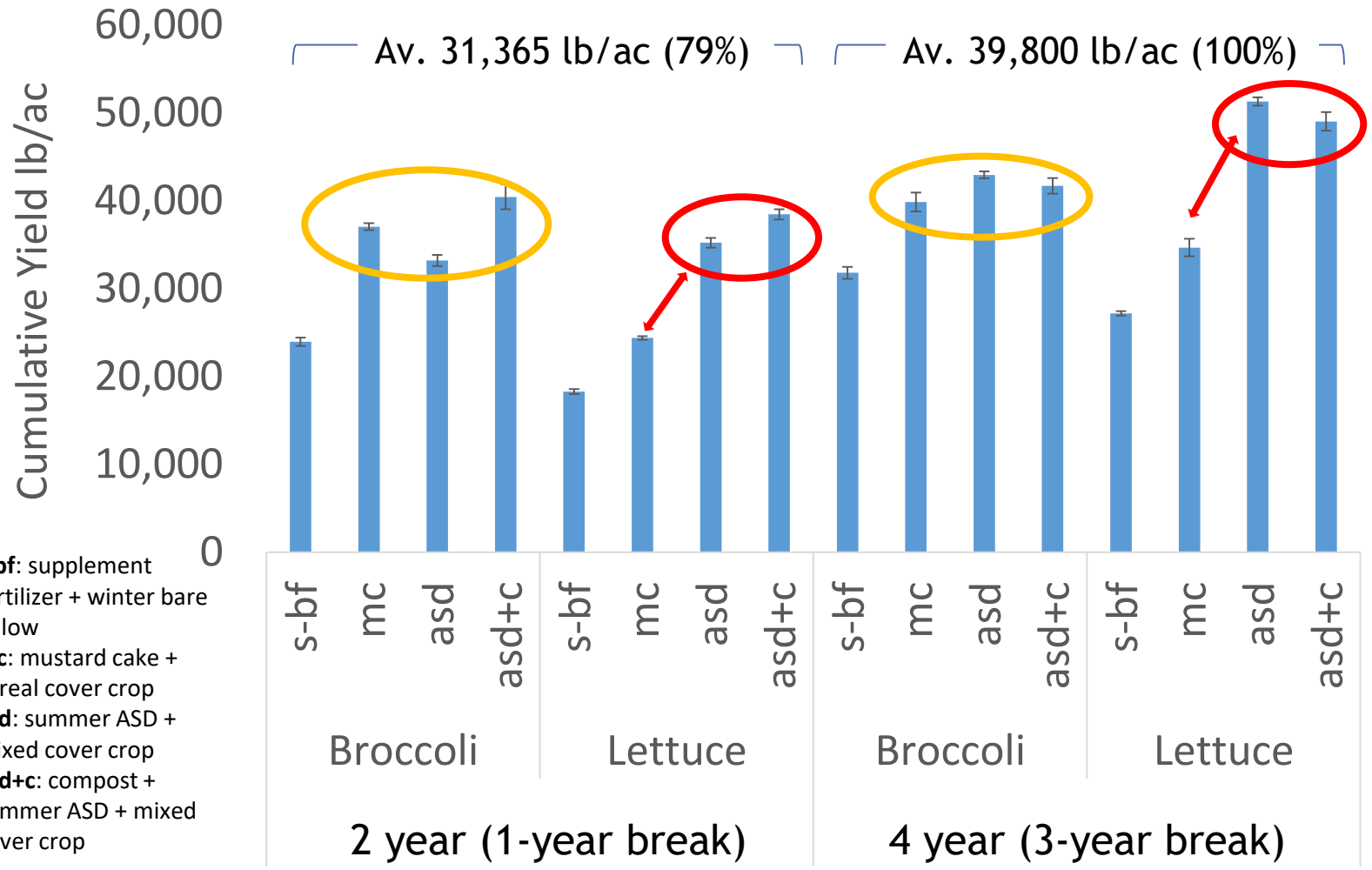


Legend Acronym	Legend	Resistance Numerical Category
R	Resistant	1
MR	Moderate Resistance	2
MS	Moderate Susceptibilty	3
S	Susceptible	4

Variety	Type	Macrophomina	Verticillium	Fusarium	Phytophthora
UCD Warrior	SD	2	3	1	2
Portola	DN	4	2	1	2
UCD Victor	SD	3	3	1	2
Camino Real	SD	4	1	3	2
Diamante	DN	3	3	1	3
Fronteras	SD	3	3	1	3
San Andreas	DN	4	2	1	3
UCD Moxie	DN	4	2	1	3
Grenada	SD	2	2	4	3
Petaluma	SD	3	2	3	3
Ventana	SD	4	3	1	3
Palomar	SD	3	3	3	3
Selva	DN	3	2	4	3
UCD Royal Royce	DN	3	2	4	3
Albion	DN	4	2	4	3
Cabrillo	DN	4	2	4	3
Merced	SD	4	3	4	2
UCD Valiant	DN	4	2	4	3
Gaviota	SD	4	3	4	3
Mojave	SD	4	3	4	3
Monterey	DN	4	3	4	3
Benicia	SD	4	4	4	3
Camarosa	SD	4	4	4	3
Seascape	DN	4	4	4	3

https://www.calstrawberry.com/en-us/Pest-Management/Breeding

8-year organic rotation trial at UCSC farm
Marketable Fruit Yield at year 8 (cv. Albion)
(*V. dahliae, F. oxysporum* f. sp. *fragariae, and M. phaseolina* infested site)



s-bf: supplement fertilizer + winter bare fallow
mc: mustard cake + cereal cover crop
asd: summer ASD + mixed cover crop
asd+c: compost + summer ASD + mixed cover crop

Evolution of Arthropod Pest Management

- 60s-80s; Chemical Revolution in Agriculture

  "The only good bug is a dead bug"

- 70s-; Integrated Pest Management (IPM)

  "Good bugs as well as bad bugs exist"

  First scouting, then treatment

NATIONAL GEOGRAPHIC

Aug. 6, 2017

Honeybees are crucial for growing crops like almonds and watermelons.

PHOTOGRAPH BY ANAND VARMA, NAT GEO IMAGE COLLECTION

BOOK TALK

Without Bugs, We Might All Be Dead

There are 1.4 billion insects per person on this planet and we need (almost) every one of them.

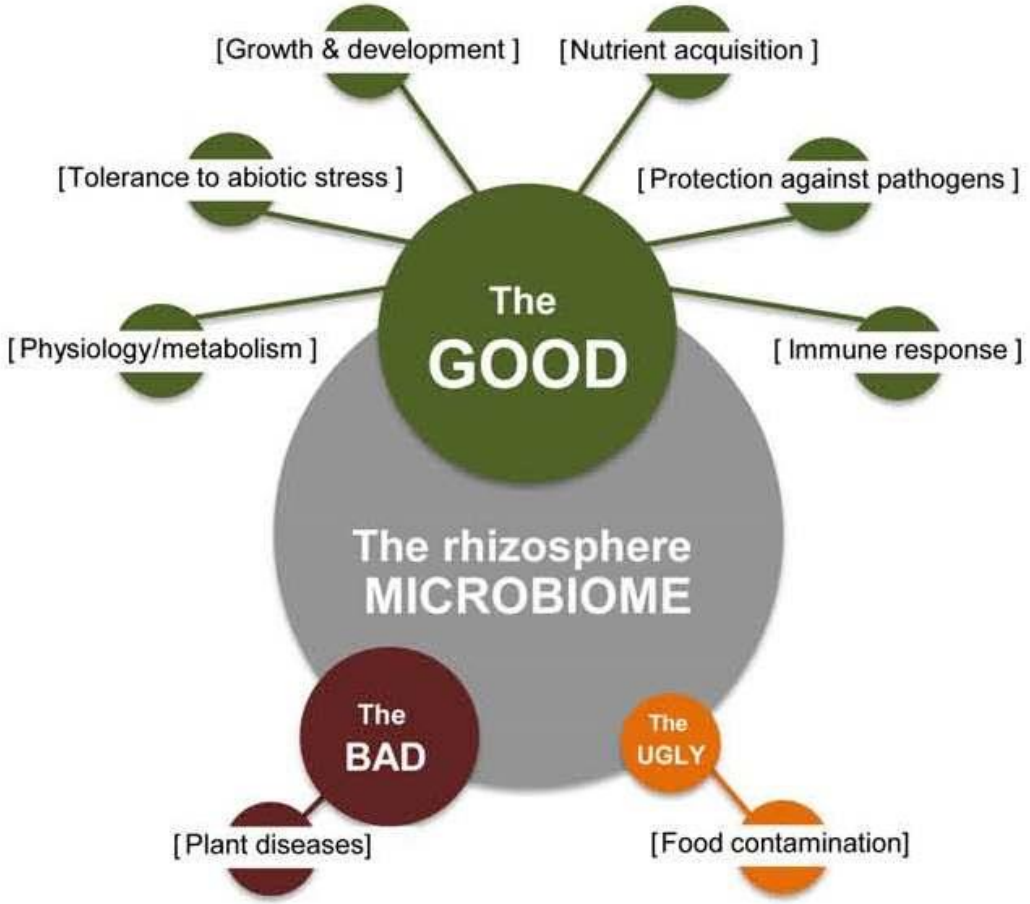
7 MINUTE READ

BY SIMON WORRALL

Integrated soilborne Disease Management (ISDM)

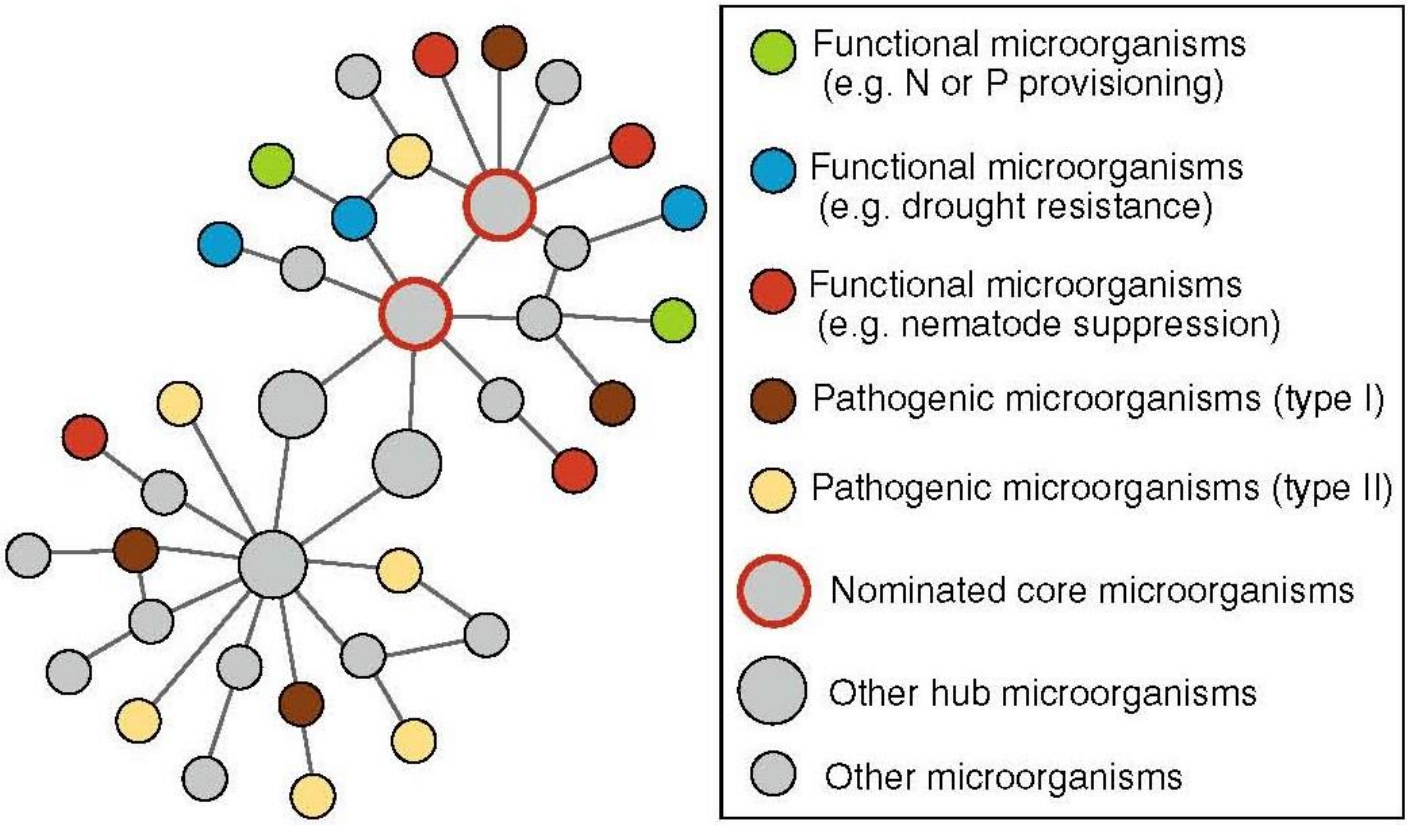
- Compared to arthropod pest IPM,
  - Developing slowly because…..
  - Difficulty in pathogen quantification
    - Rapid/accurate quantification using molecular approaches ……. “Scouting” of soilborne pathogens is becoming practical
  - Prevention only, no reactive treatments available
  - Not many non-fumigant approaches available
    - Need more research while we still have access to fumigant

The Good, The Bad, and The Ugly



(Mendes et al., 2013, FEMS Microbiology review)

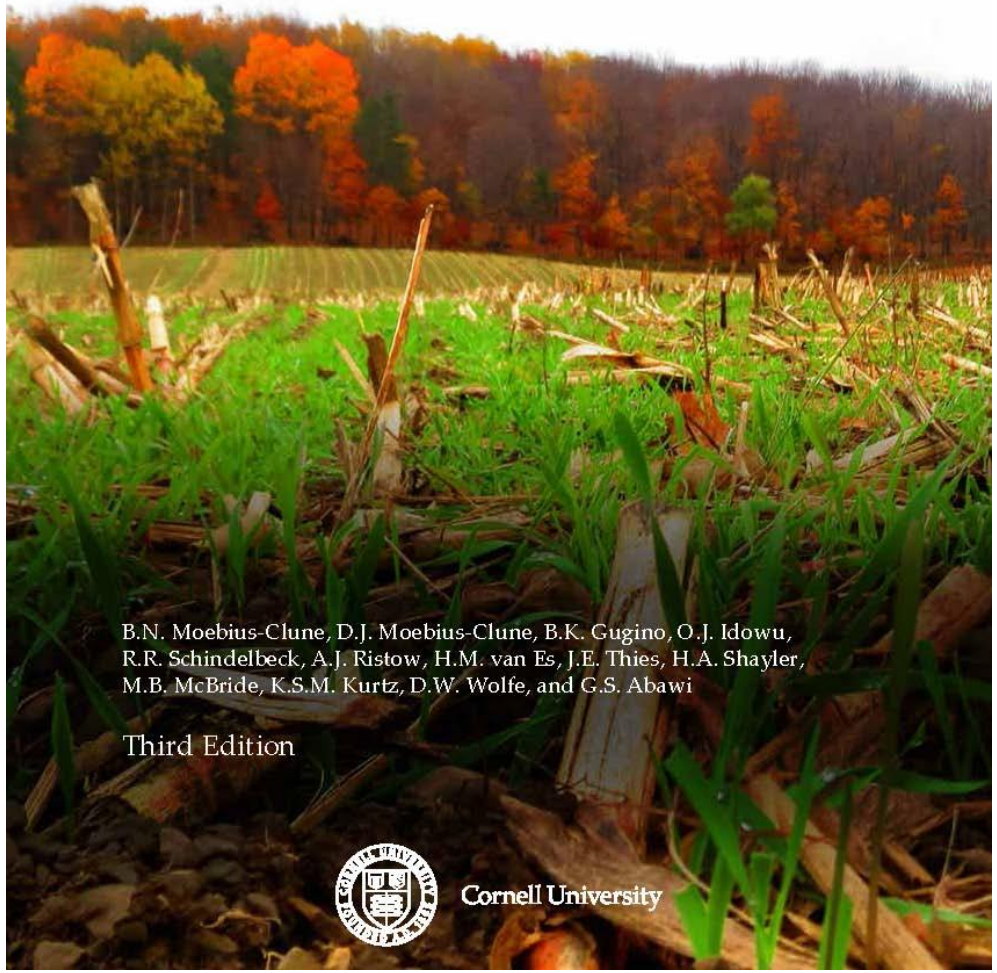
Core Microbiomes



(Toju et al., 2018. Nature Plants)

Comprehensive Assessment of Soil Health

The Cornell Framework



B.N. Moebius-Clune, D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M. Kurtz, D.W. Wolfe, and G.S. Abawi

Third Edition

Cornell University

Measured Soil Textural Class: **silt loam**

Sand: **2%** - Silt: **83%** - Clay: **15%**

Group	Indicator	Value	Rating	Constraints
physical	Available Water Capacity	0.14	37	
physical	Surface Hardness	260	12	Rooting, Water Transmission
physical	Subsurface Hardness	340	35	
physical	Aggregate Stability	15.7	19	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
biological	Organic Matter	2.5	28	
biological	ACE Soil Protein Index	5.1	25	
biological	Soil Respiration	0.5	40	
biological	Active Carbon	288	12	Energy Source for Soil Biota
chemical	Soil pH	6.5	100	
chemical	Extractable Phosphorus	20.0	100	
chemical	Extractable Potassium	150.6	100	
chemical	Minor Elements Mg: 131.0 / Fe: 1.2 / Mn: 12.9 / Zn: 0.3		100	

Overall Quality Score: **51** / Medium

Integrated Soil Health Management (ISHM) (Concept)

Goals:
Multiple ecological services
- Crop production
- Pest management
- Water conservation (quantity & quality)
- Biodiversity conservation
- C-sequestration, GHG emission regulation
- Improved food safety

ISHM

Location specific,
Knowledge intensive

vs. fumigation approach
Location general,
Chemical intensive

Soil health diagnosis

- ✓ **Physical, biological and chemical soil health test**
  - **Labile C, N, enzyme. etc.**
- ✓ **Molecular-based biological test *(crop specific)***
  - **Pathogenic/beneficial microbes**
  - **Soil microbial community, diversity, keystone species for suppressiveness**

Develop strategies (using a Decision support tool "OrganicCropManage")

- **Crop rotation/cover crop**
- **Resistant variety**
- **ASD (C-source options), solarization, steam, MSM**
- **Soil (biological) amendments/fertilizers**
- **No-till, reduced-till**

Thank you!

Question?

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SLUG
SANTA CRUZ