Harnessing the nitrogen cycle: Chemical ecology driving future innovations in nitrogen management

16-05-2025

My training and education

2007-2010
Biochemistry
Microbiology
Genetics

BSc Univ Settat

2010-2012
Sustainability
Crops resilience

MSc UCAM

2012-2016
Germination physiology
Seedling chemical ecology
Chemometrics

PhD UPJV

2016-2017
Pharmacognosy
Analytical chemistry

Research assistant

2017-2021
Soil Metabolomics
Root Microbiome
Data integration

Post Doc UvA

2022-
Chemical ecology
Microbial ecology

SE Syngenta

Content.

- Importance of innovation in agro-industry
- The central role of microbial life in the agroecosystem
  - Plant-microbe interactions
  - How to select beneficial microorganisms
- Studying soil chemical ecology to speed up innovation in agro-industry
  - Parasitic plants
  - Parasitic nematodes
  - Nitrogen management

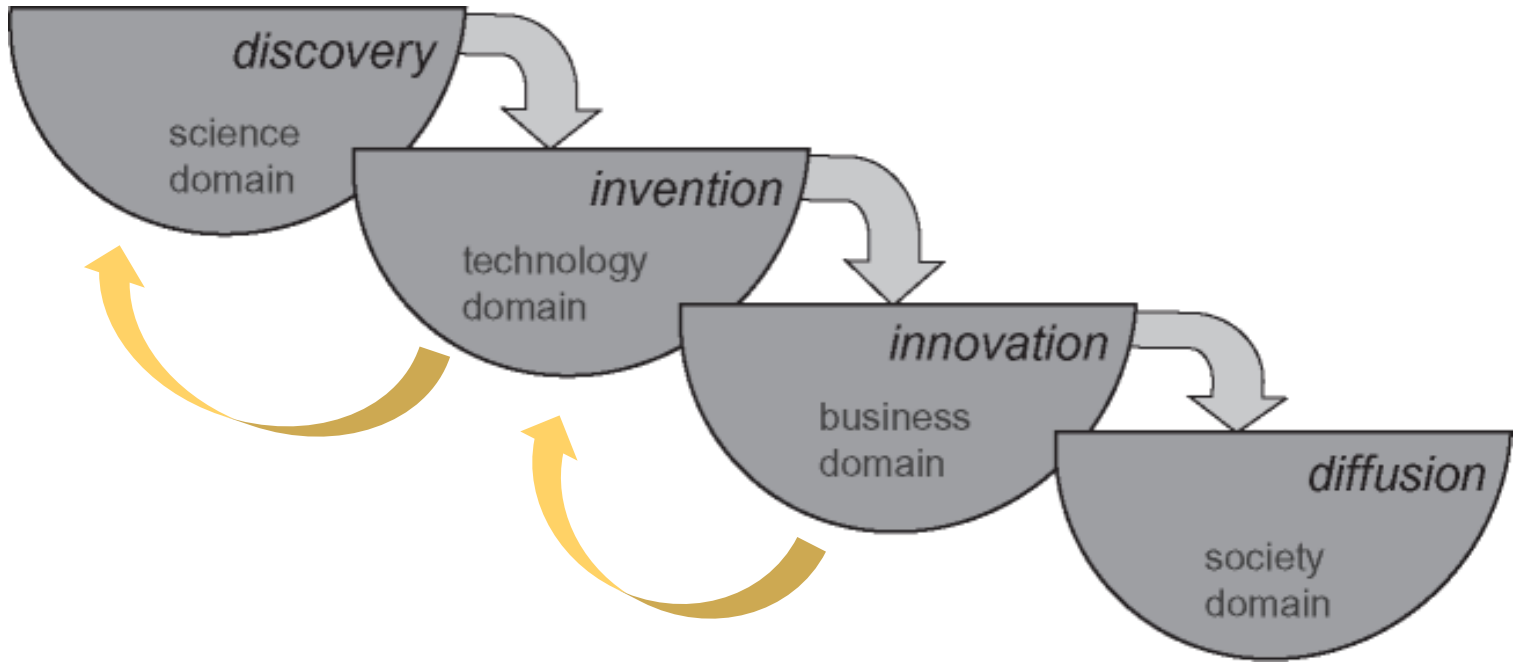
Central role of R&D innovation in agro-industry

16-05-2025

The innovation process in agriculture

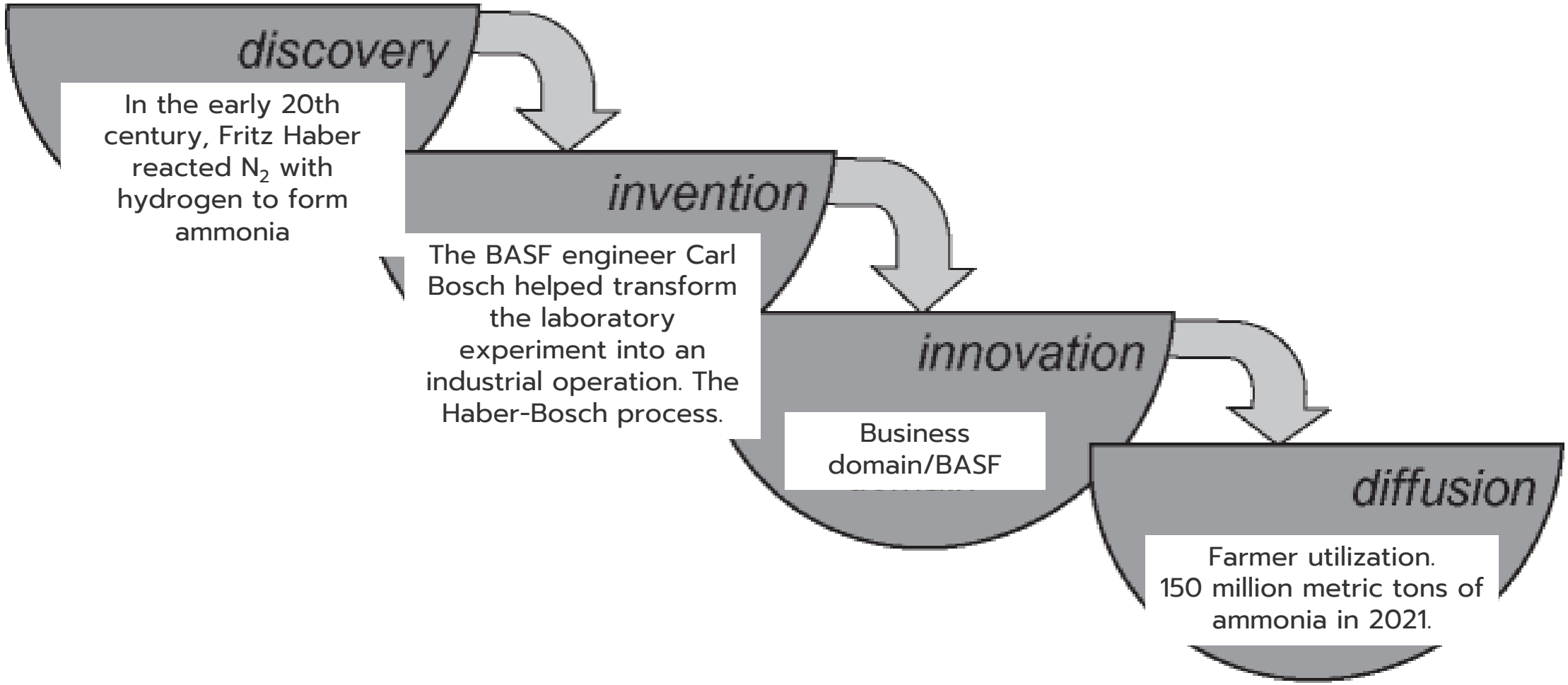
Introduction of new or improved products or processes to enhance effectiveness, competitiveness, resilience to shocks, or environmental sustainability.

Technology Push



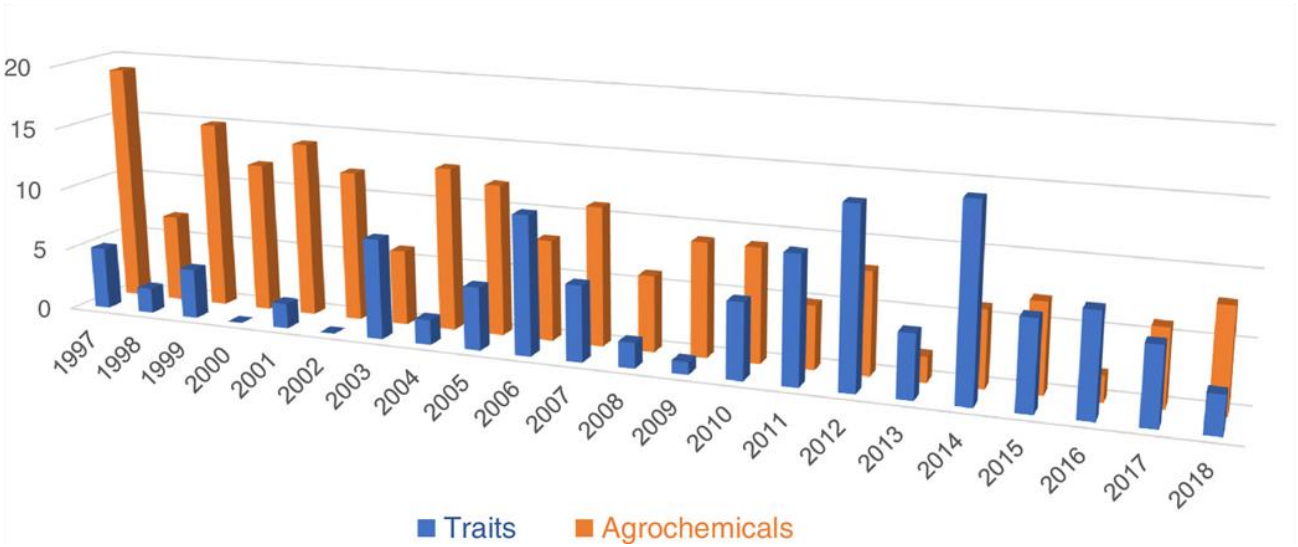
Customers Needs
Demand pull

From discovery to innovation: Haber-Bosch process



https://phys.org/news/2018-08-ammonia-synthesisthe-greatest-20th-century.html

Agrochemical industry development, trends in R&D



https://scijournals.onlinelibrary.wiley.com/doi/full/10.1002/ps.5728

«...innovation related to soil will be a massive opportunity for farmers and society.»
Jeff Rowe, CEO of Syngenta Group

A successful use of microbes as plant protection solution will strongly depend on our understanding on how they are recruited.

The central role of chemical ecology in the agroecosystem

Soil microbial community

- Bacteria
- Archaea
- Fungi

Bergna, 2015

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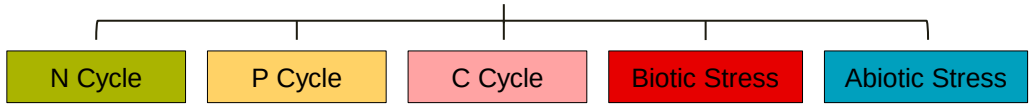
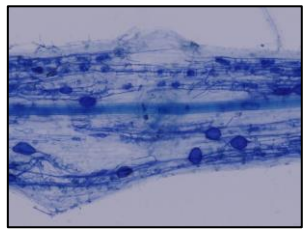
Contributions of soil functions to ecosystem services

Soil Properties and processes	Soil functions	Ecosystem services
Soil properties Texture, humus pH, Bulk density, microbial biomass, Mineralogy. **Soil processes** Decomposition, Food webs, Nitrification, Sorption, Mineralization…	**Soil sub function** water cycle regulation, nutrient cycle, carbon pool regulation, habitat for plants and microorganisms, Filtering and buffering	**Ecosystem service** Agricultural production, Climate regulation, Flood control, Water purification.

Haines-Young and Potschin (2008).

SOIL HEALTH



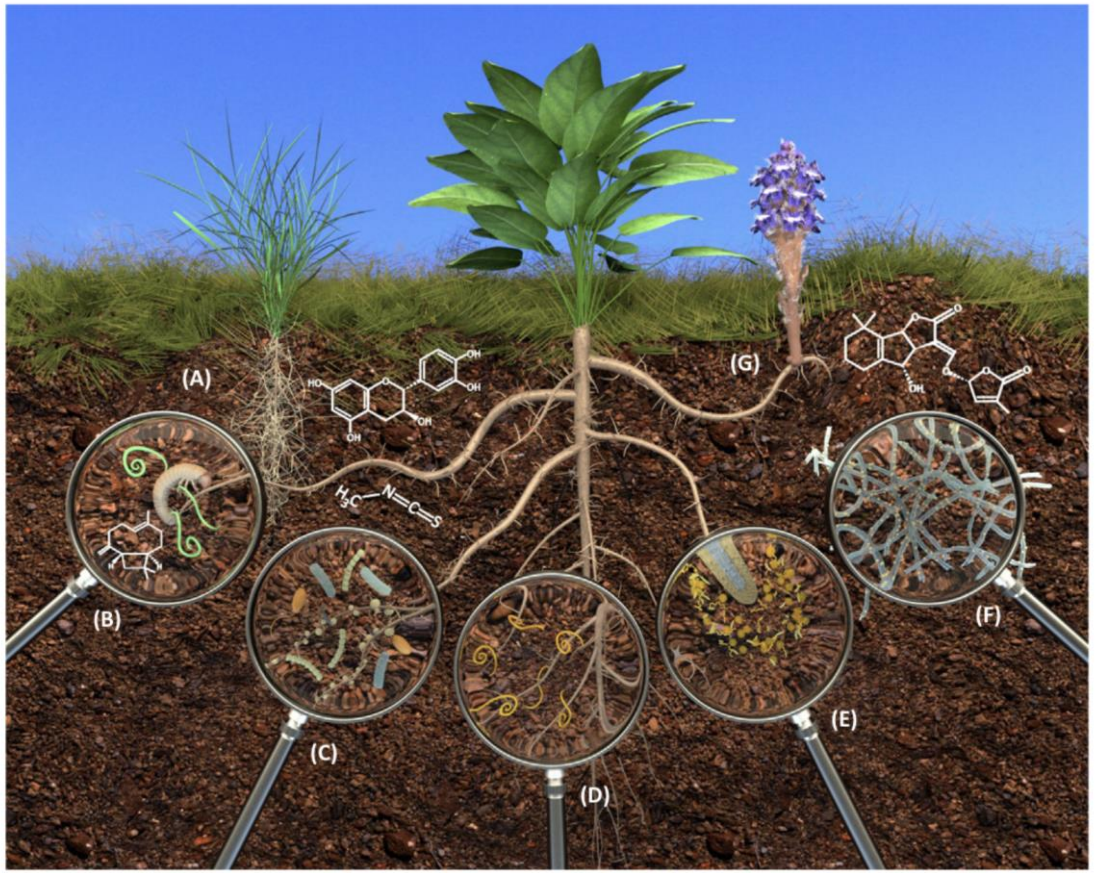


- Soils deliver a wide range of ecosystem services, including food production, water and climate regulation and biodiversity
- Our' soil is a fundamental resource for the sustainment of every human activity.
- Its management has never been more important than in our times.

Plant below-ground chemistry: a bridge to rhizosphere

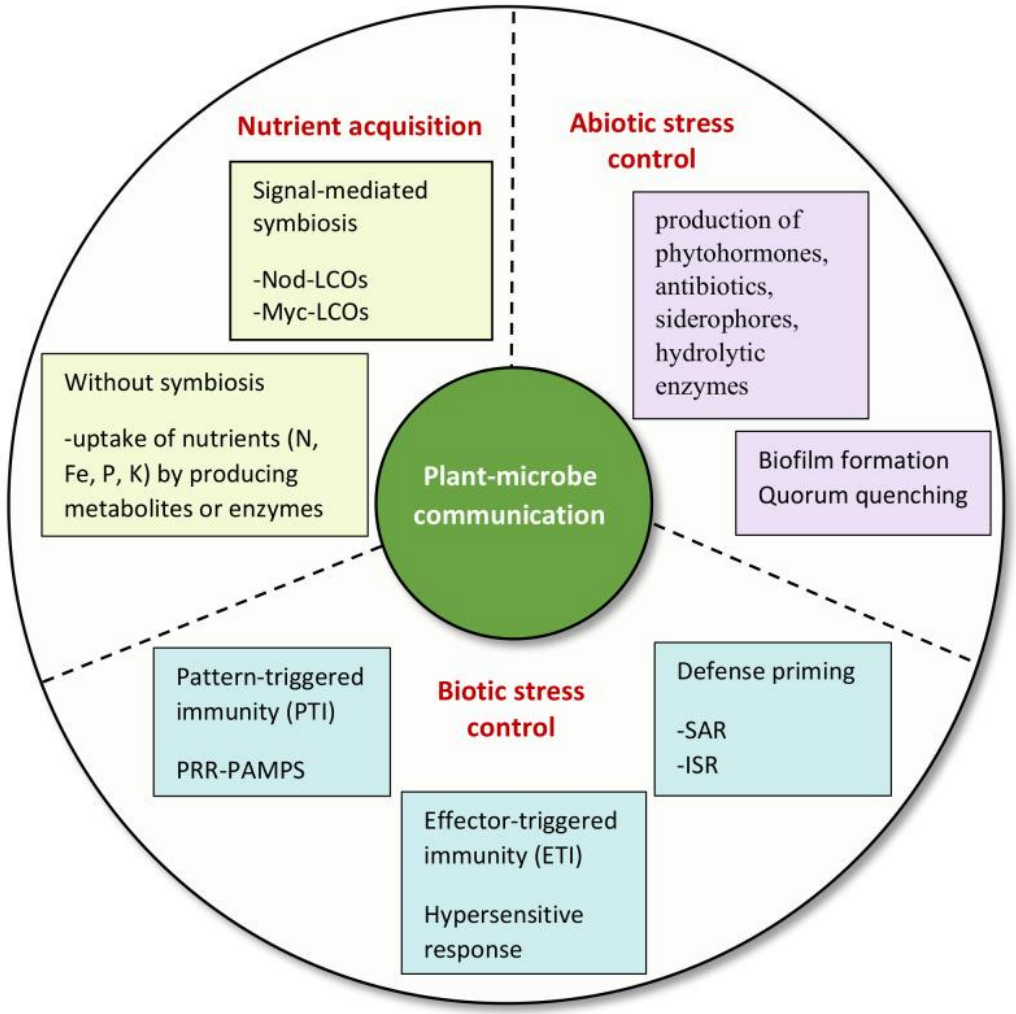
"Root exudates contain an array of primary and secondary plant metabolites that can attract, deter, or kill belowground insect herbivores, nematodes, and microbes, and inhibit competing plants. Metabolomics of root exudates can potentially help us to better understand this chemical dialogue." Nicole M. van Dam and Harro J. Bouwmeester, 2016

- Allelopathy
- Hatching of cyst nematodes
- Hyphal branching in arbuscular mycorrhizal fungi
- Modulation of rhizosphere microbiome
- Germination of parasitic plant



Nicole M. van Dam and Harro J. Bouwmeester, 2016

Significance of Signaling in Plant–microbiome Interaction



https://pmc.ncbi.nlm.nih.gov/articles/PMC9147336/

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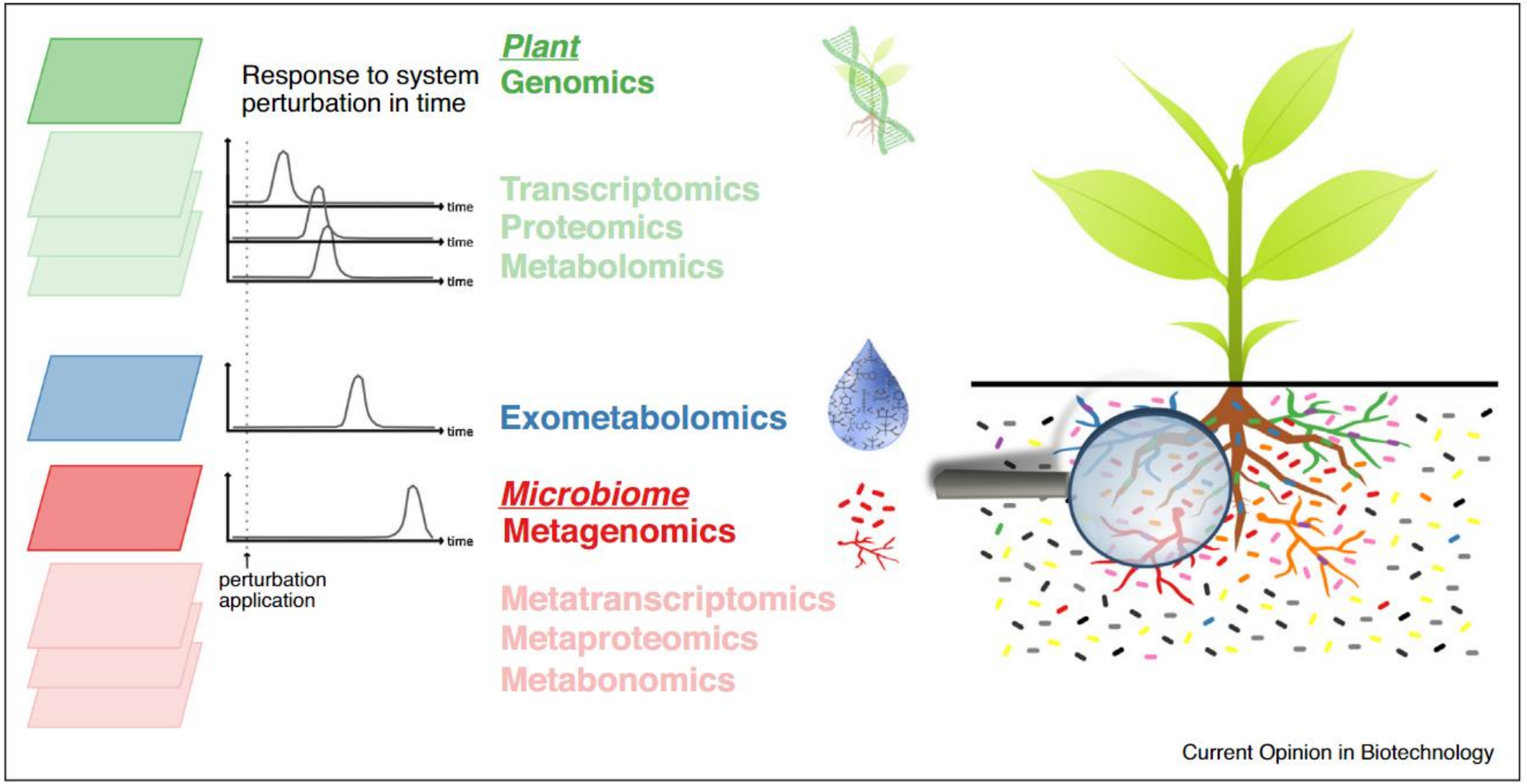
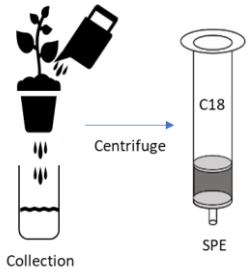
Importance of data acquisition to unravel rhizosphere plant-microbiome interaction

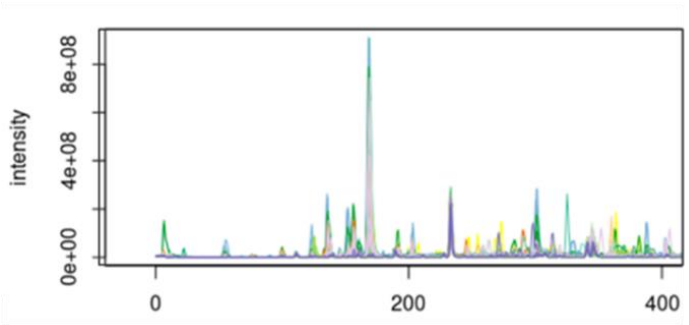


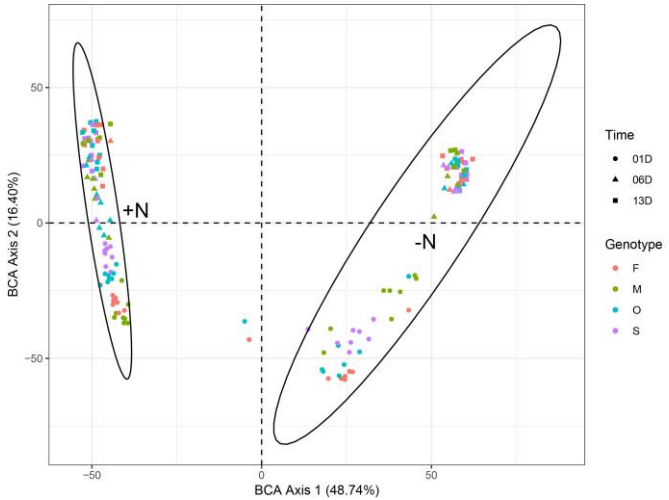
Zancarini et *al.*, 2021

A multi-omics approach to support in the discovery of signaling molecules

Metabolomics







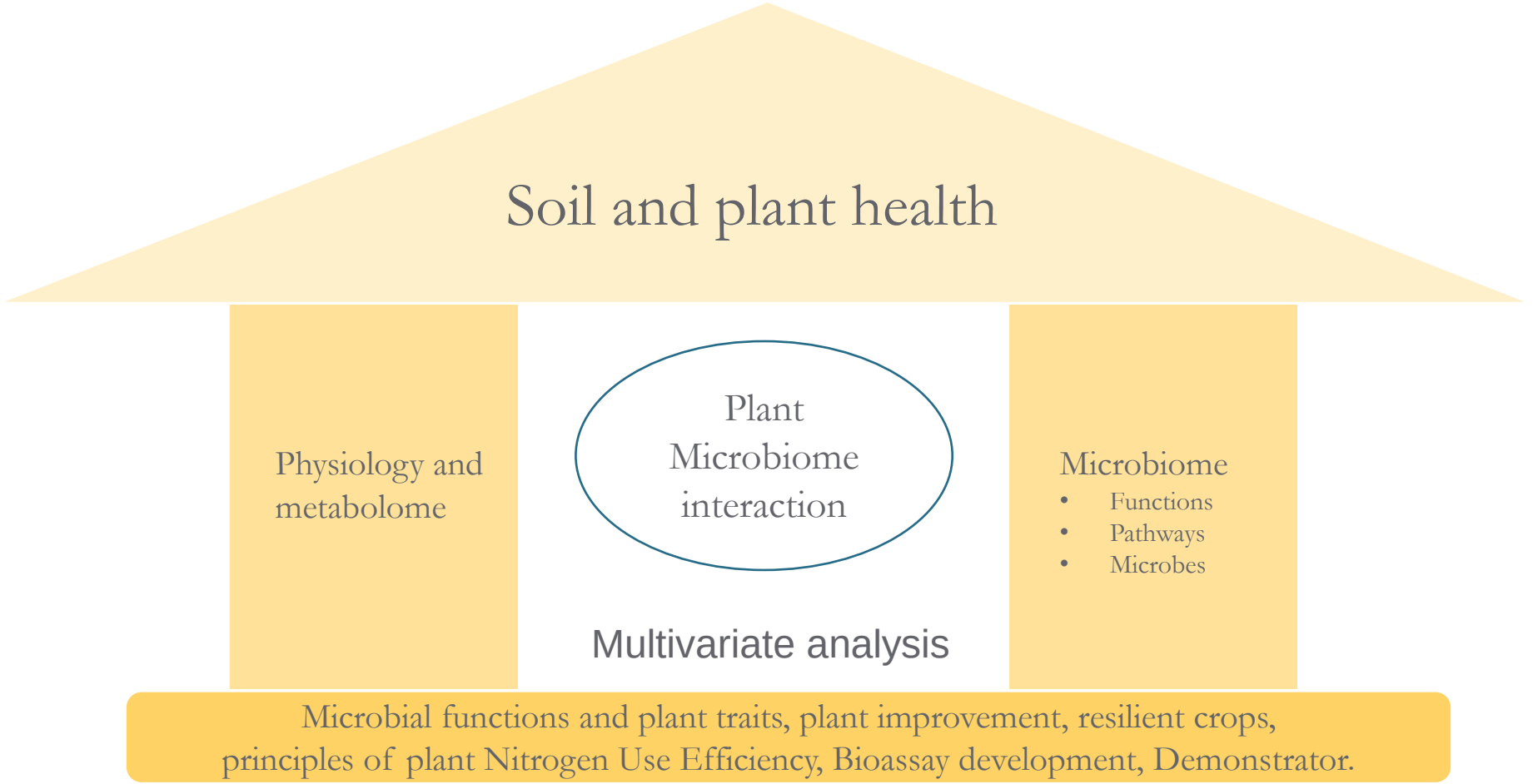
Explanatory factor	Explained variation (%)
Nitrogen	22
Time	17
Genotype	2

Microbiome composition

- Mechanisms and strategies of plant microbiome interactions to mitigate nitrogen stress
- New concepts definition for Nitrogen cycle management (i.e. Bacterial adaptation)

Integrating Metabolomic and Microbiome Studies to Drive Agricultural Innovation

Deciphering the language used by plants to cope with abiotic stress



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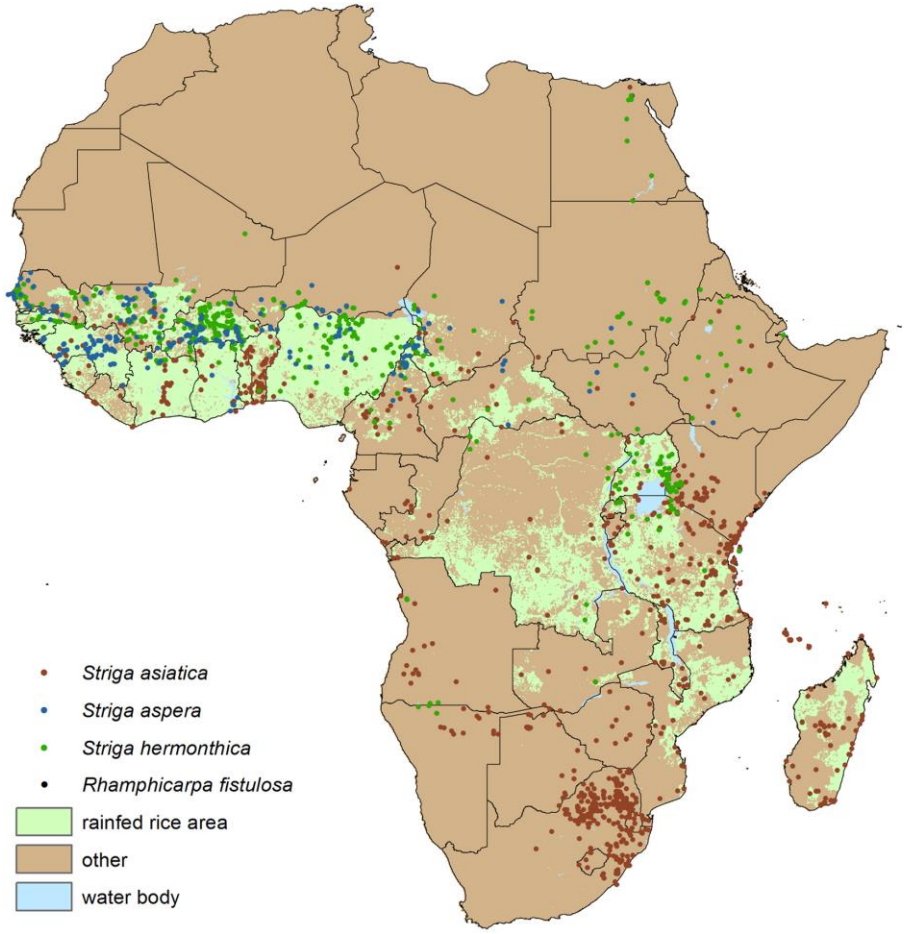
What are the main crops in Africa

Crop	Africa (2012)	
	Area (ha)	Production (t)
Maize	34,075,972	70,076,591
Millet	19,998,008	16,008,838
Rice, paddy	11,206,813	28,798,202
Sorghum	23,142,595	23,350,064
Wheat	10,224,952	24,704,201
Total	**98,226,080**	**162,422,507**

FAOSTAT | © FAO Statistics Division 2015 | 04 October 2015

Striga in Africa

- Witchweed is a common name for *Striga*
- parasitizing Sorghum, Maize, Rice (about 200 million $ loss/year) and Millet
- *Striga* can build a seed bank, up to 20 years
- *Striga* symptoms are chlorosis, wilting
- *Striga* can cause a partial or complete yield loss depending on the infestation rate



Striga distribution in Africa

Rodenburg et *al*., 2016

Striga management and control measures

Seed bank depletion

- Suicidal germination

Cover crop systems

- Desmodium

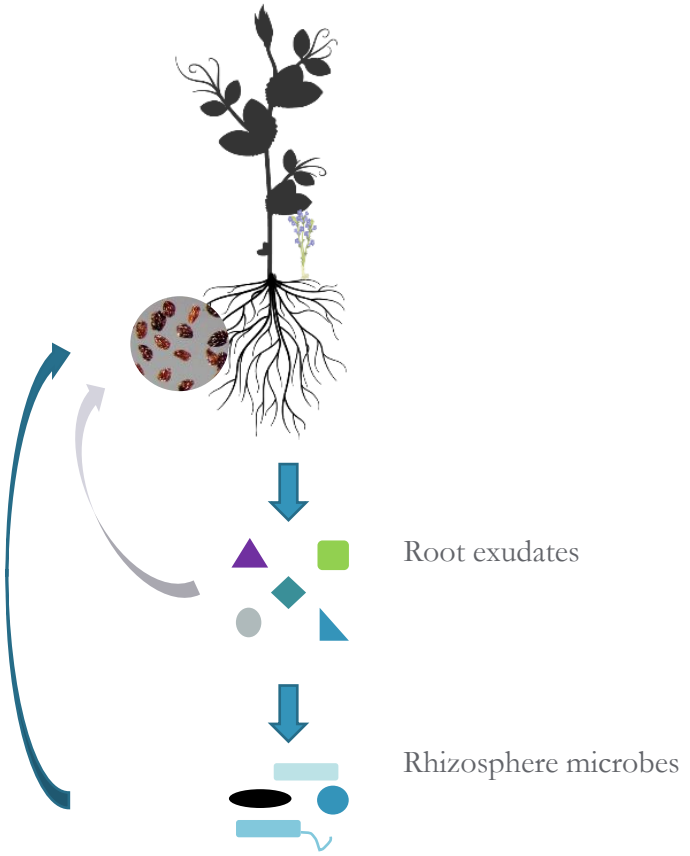
Agrochemicals

- Fertilizers
- Pesticides

Resistant genotypes

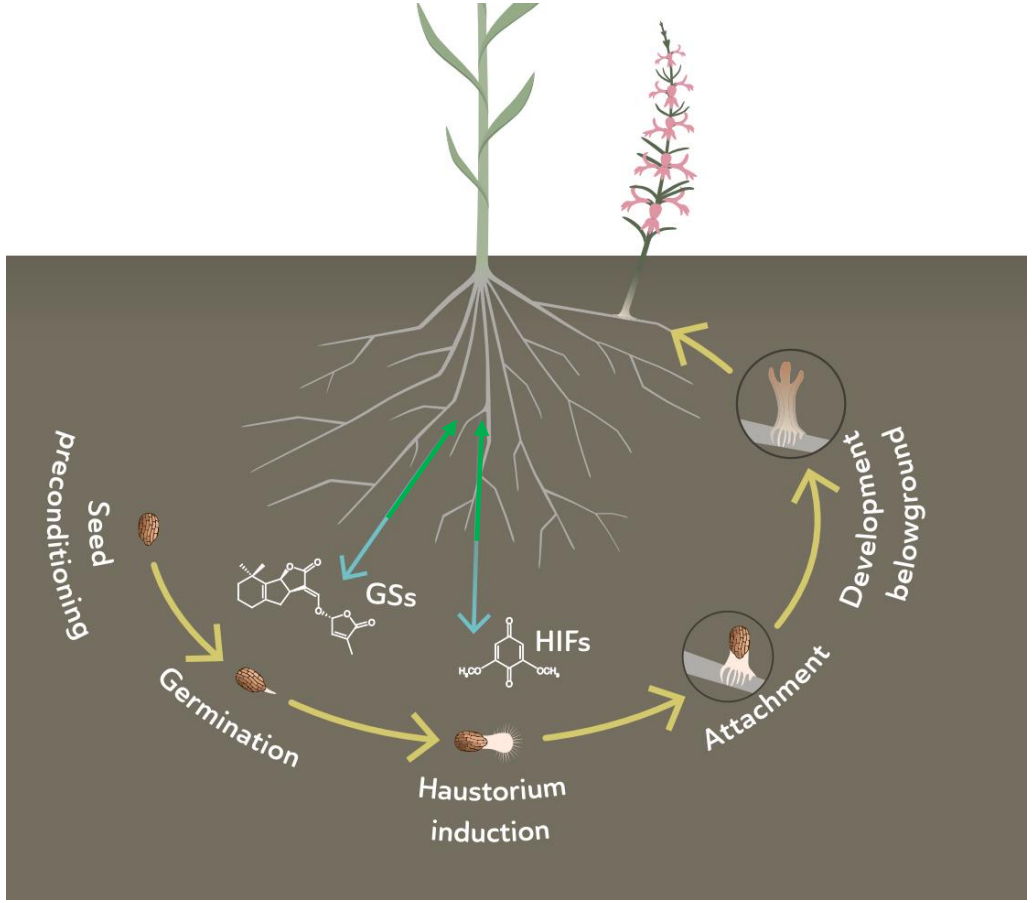
- Low germination stimulants
- barriers

Plant soil dialogue



Can chemical and microbial ecology teach us how to combat the parasitic weed scorch, *Striga*?

The plant-parasitic plant-microbes interaction, a tango for 3



Bouwmeester et *al.*, 2020

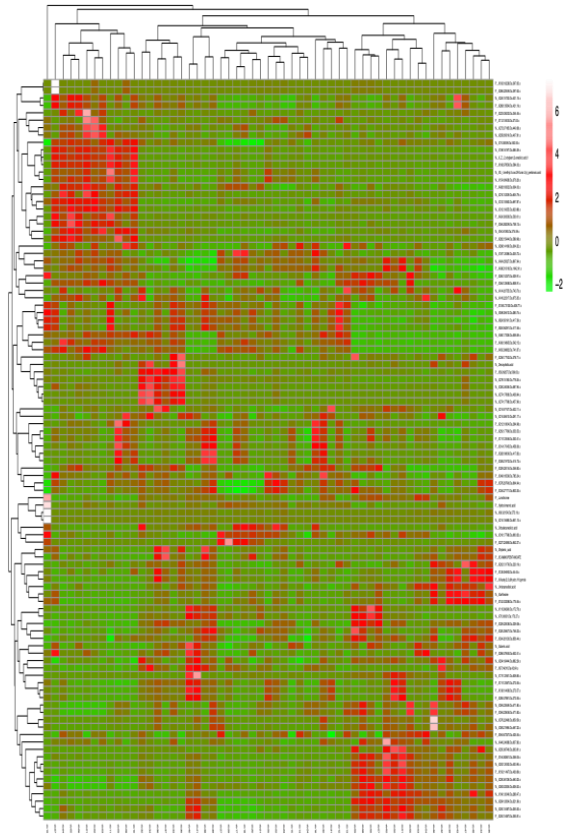
MICROBES CAN HELP FEED THE WORLD

How can plant microbiome interfere in the interaction between the host and the parasite

- In the early phases of the life cycle, host plant is communicating with parasitic plant by emitting germination stimulants and haustorium inducing factors

The plant-parasitic plant interaction

- Host plant-parasitic plant interaction, an opportunity to study plant-plant communication

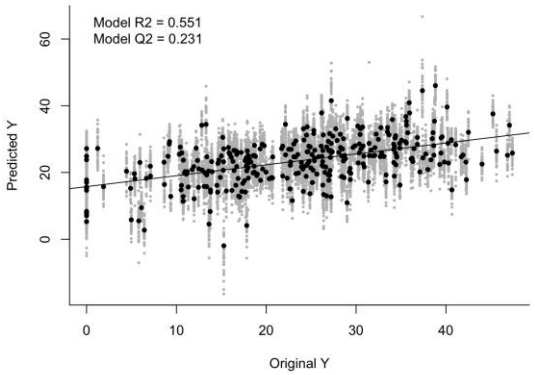


Plant chemical composition

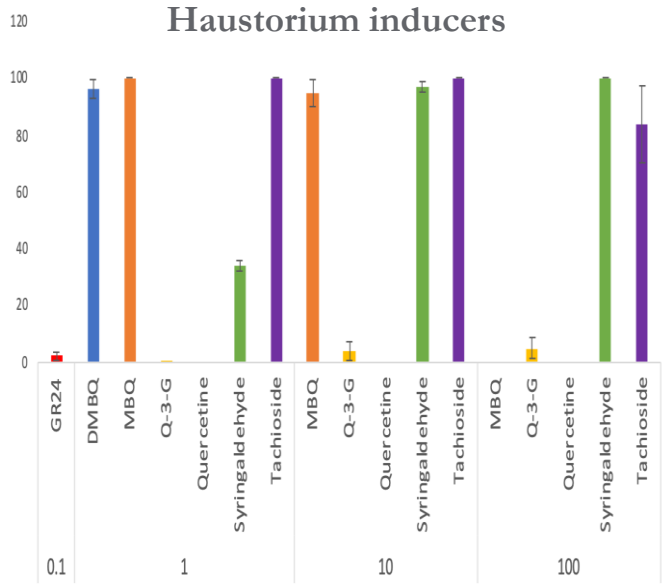
Mass Spectrometry of Biomolecules

Parasite susceptibility response

- Germination
- Haustorium formation
- Growth

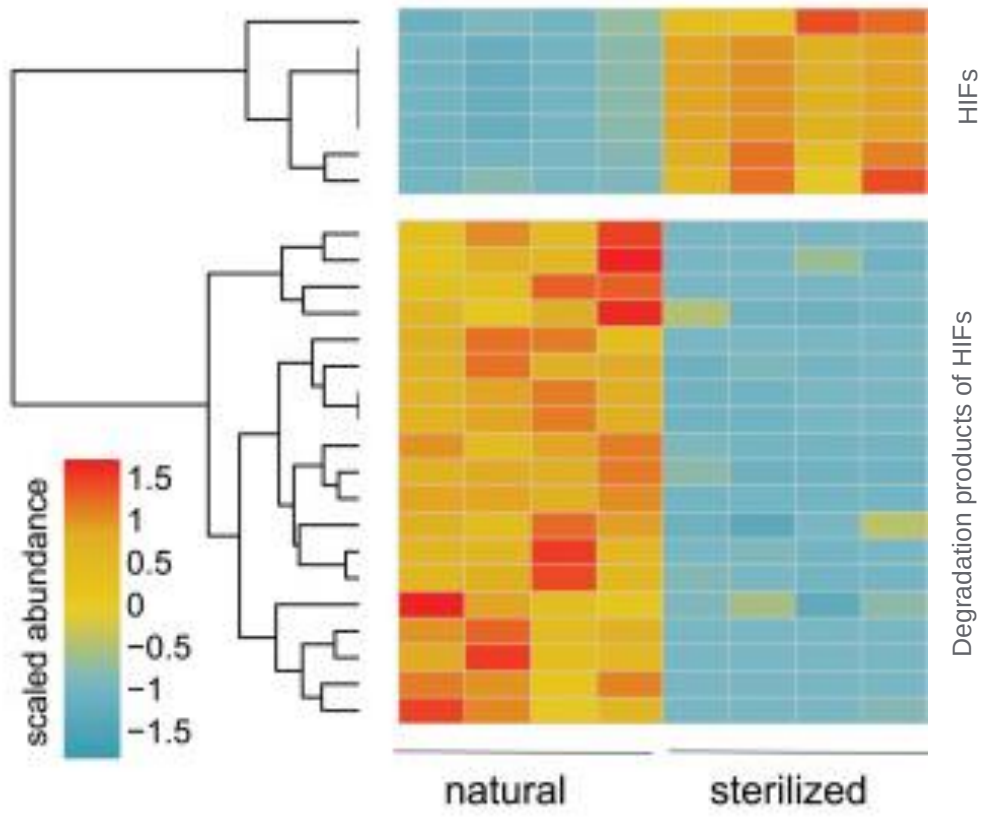


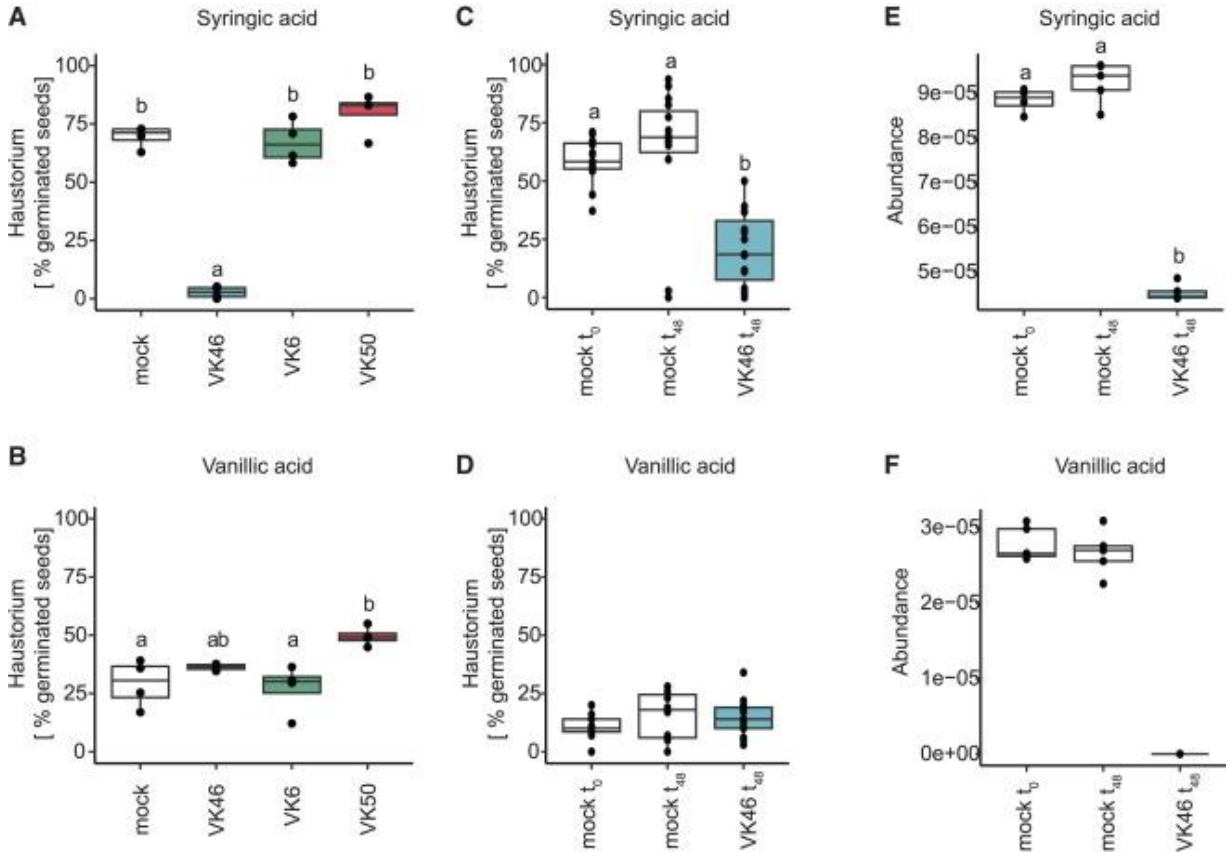
Random forest for identification of new plant-parasitic plant signalling compounds



The plant-parasitic plant-microbes interaction, a tango for 3

- Microbiome can disregulate the plant-parasitic plant interaction
  - Signaling compounds (haustorium inducing factors) degradation
  - Plant is selecting for microorganisms able to degrade host chemical cues





The plant-parasitic plant-microbes interaction, a tango for 3

Cell Reports

CellPress
OPEN ACCESS

Article

The soil microbiome modulates the sorghum root metabolome and cellular traits with a concomitant reduction of Striga infection

Dorota Kawa,[1,2,3,*] Benjamin Thiombiano,[4] Mahdere Z. Shimels,[5] Tamera Taylor,[1,6] Aimee Walmsley,[4] Hannah E. Vahldick,[1] Dominika Rybka,[5] Marcio F.A. Leite,[5] Zayan Musa,[1] Alexander Bucksch,[7,8,9] Francisco Dini-Andreote,[5,10,11] Mario Schilder,[4] Alexander J. Chen,[1] Jiregna Daksa,[1] Desalegn W. Etalo,[5,14] Taye Tessema,[12] Eiko E. Kuramae,[5,13] Jos M. Raaijmakers,[5] Harro Bouwmeester,[4] and Siobhan M. Brady[1,15,*]

doi:10.1093/plphys/kiaa066 PLANT PHYSIOLOGY 2021: 185: 1292–1308

Plant Physiology

Adaptation of the parasitic plant lifecycle: germination is controlled by essential host signaling molecules

Harro Bouwmeester ,[1,*,†] Changsheng Li ,[1] Benjamin Thiombiano ,[1] Mehran Rahimi[1] and Lemeng Dong [1]

Maize resistance to witchweed through changes in strigolactone biosynthesis

C. LI, L. DONG, J. DURAIRAJ, J.-C. GUAN, M. YOSHIMURA, P. QUINODOZ, R. HORBER, K. GAUS, J. LI, [...], AND H. J. BOUWMEESTER

+21 authors Authors Info & Affiliations

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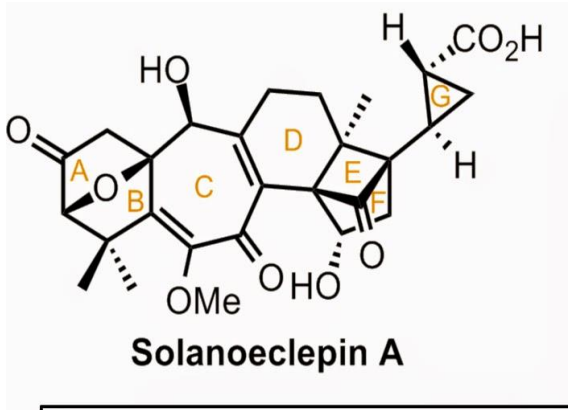
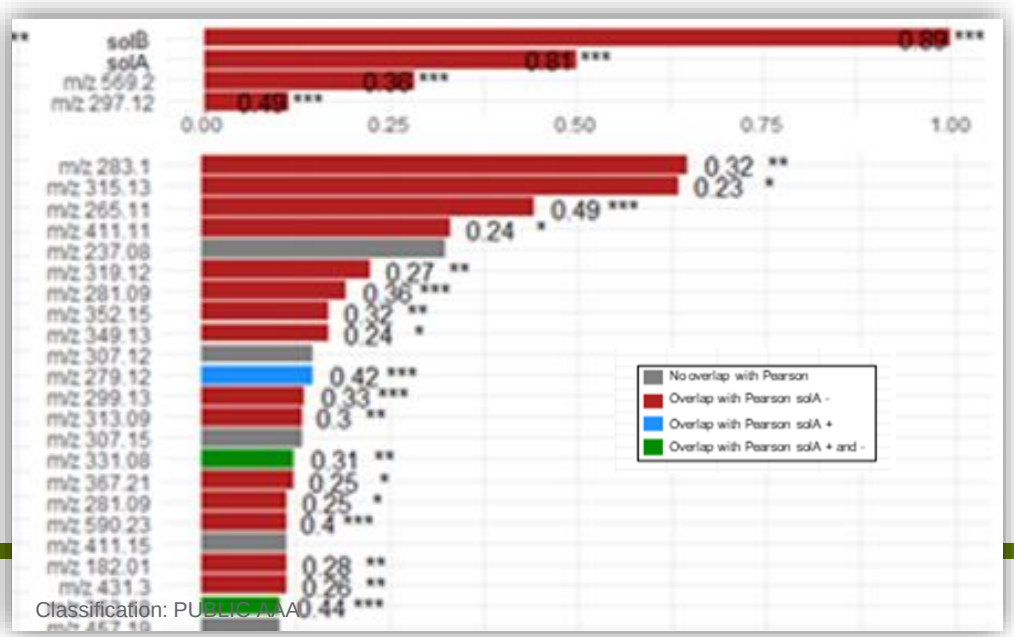
Identification of novel hatching stimulant from potato cultivars

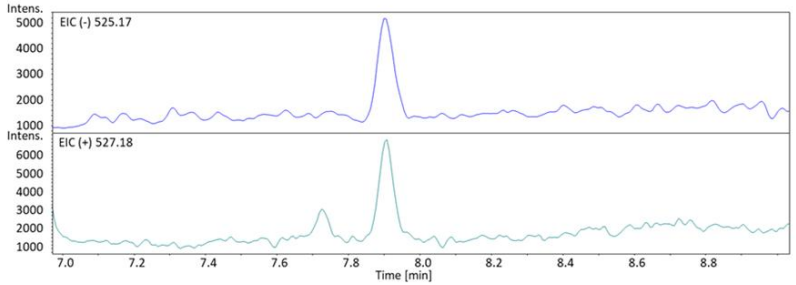
- Potato cyst nematodes (PCNs), i.e. *Globodera rostochiensis* and *G. pallida* cause sever loses in potato fields

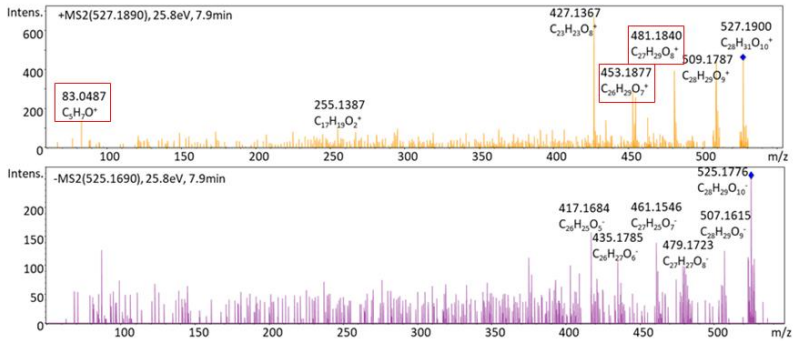


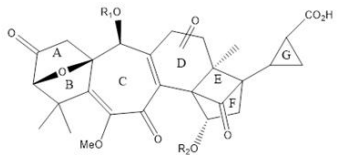
Solanoeclepin A

- Solanoeclepin A is a triterpenoid compound found in the root exudates of potato and tomato
- Solanoeclepin A is one of the major hatching stimulant for Potato Cyst Nematode









Chemical formula: $C_{28}H_{30}O_{10}$
$R_1 = CH_3$ and $R_2 = H$
or
$R_1 = H$ and $R_2 = CH_3$

Recap

- Better understanding on the below-ground chemical communication between Striga and sorghum, which will help define the most important targets for Striga resistance breeding in sorghum.
- Multivariate models that combine metabolic profiles with phenotypic data can be used to identify chemical features involved in biological processes (host plant-parasitic plant interaction).
- Soil microbiome can interfere with the signaling between host and parasite.

Age Smilde

Johan Westerhuis

AgBiome™

WESTERDIJK FUNGALBIO DIVERSITY INSTITUTE

NIOO NEDERLANDS INSTITUUT VOOR ECOLOGIE (NIOO-KNAW)

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Ethiopian Institute of Agricultural Research (EIAR)

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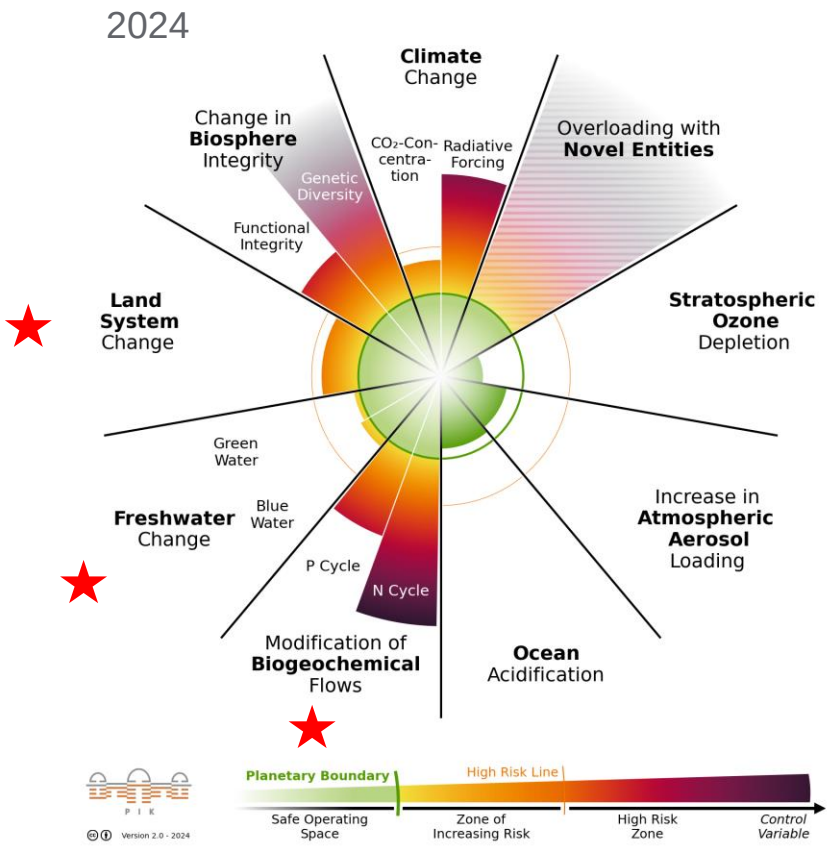
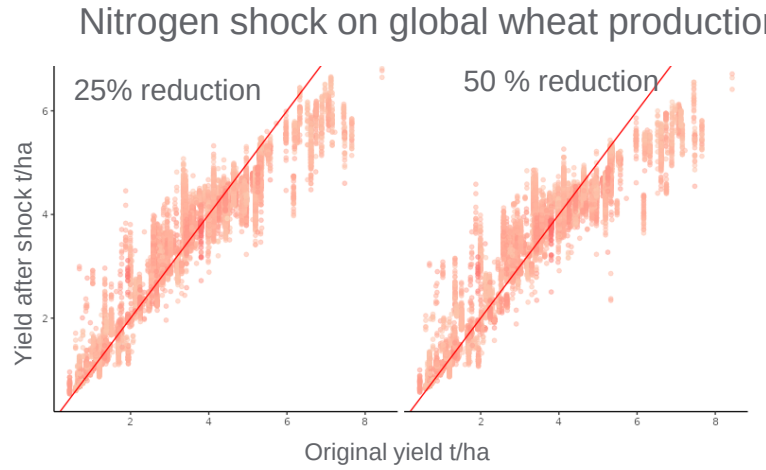
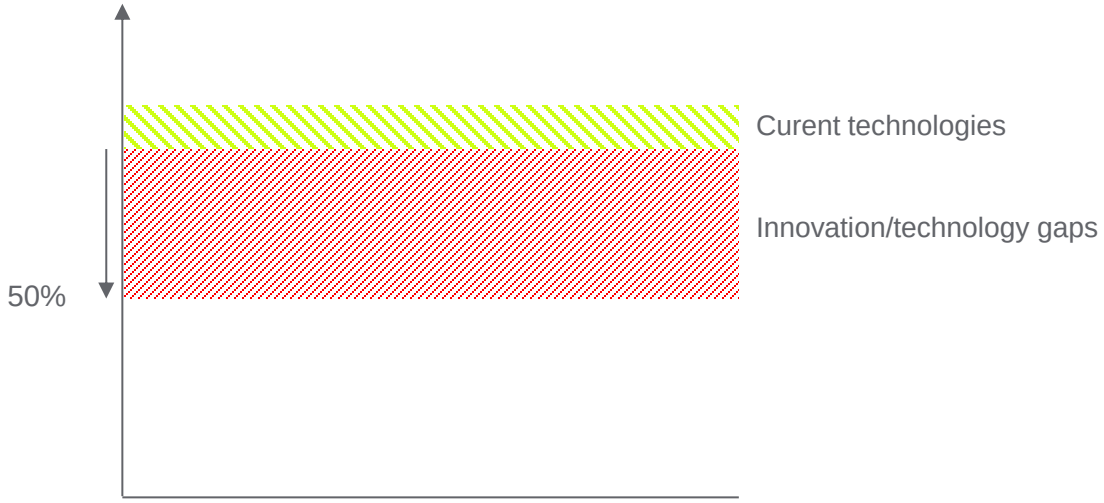
Chemical ecology driving innovations in nitrogen management

Planetary boundaries, a “Safe Operating Space” for Humanity



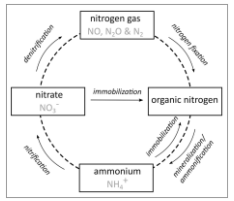
https://pubs.acs.org/doi/10.1021/acsenergylett.2c02627





Multi-omics approaches to support in the discovery of natural products involved in plant nitrogen acquisition strategies.

Know functions modulation

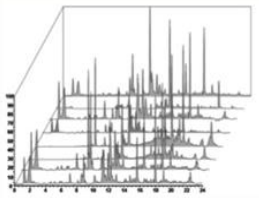


Hypothesis driven

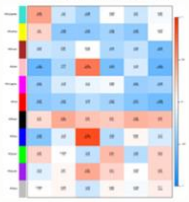
Functional screening bioassays

- Biochemical
- Molecular
- Others

Untargeted metabolomics



Pearson Correlation Coefficient

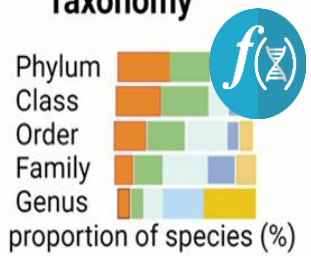


Unknown concepts

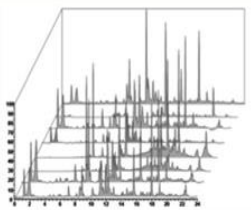
Holistic approach

Unbiased

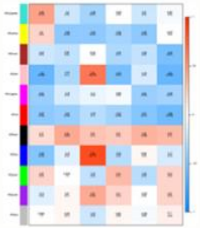
Taxonomy



Untargeted metabolomics



Pearson Correlation Coefficient



Hypothesis

1.....n

Prioritarisation

1, 5, 8

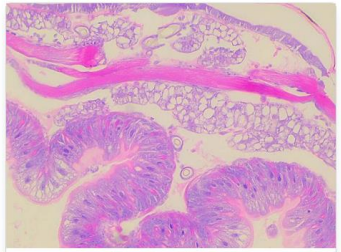
Conclusions

- Chemical ecology is a powerful approach for identification of new hits, unfortunately, some technical challenges are still limiting.
- We combine chemical, microbial ecology and soil functions to identify chemical features that play a crucial role in soil biological processes.
- Holistic approach that integrates millions years of evolution between plants and microorganisms will give us a better understanding of below-ground plant microbiome interaction.
- This will help define the most important targets for improved plant resilience and designing new agrochemicals inspired from nature with a higher chance for sustainability.

Shoots by Syngenta™ : Accelerate innovation through collaborations

View all our live challenges which have specific goals and criteria, where we are seeking brilliant minds to help us solve.

Soil restoration solutions



Advancements in 3D tissue proteomics mapping workflows

Help us advance biocontrol of soil insect pests

"Around the world, soil degradation is holding back the potential productivity & sustainability of the farms we all depend on. We want to collaborate with innovators that have novel solutions for soil restoration so that we can put them in the hands of farmers to solve this grand challenge." **Matthew Wallenstein,** Chief Soil Scientist, Syngenta

Breakthrough solutions that demonstrably improve one or more physical, chemical and/or biological properties which are indicators of soil functionality (including but not limited to:)
Physical properties
Chemical properties, e.g.: Desalinization, Soil Ph, **Soil nutrient capacity**
Biological properties, e.g.: Carbon sequestration and nitrogen mineralization, Microbiome functionality, Reduction of greenhouse gas emissions

- Early evidence of efficacy/demonstration of proof of concept
- Information on which soil types to target to achieve maximum effectiveness from the solution

Collaboration

Access to expertise including our 6,000+ forward thinking scientists

Realize real world potential from your research

Through our global reach and market knowledge we can help deliver impact from your research or technology

Funding and backing

We are able to fund selected projects to drive toward commercialization through our global footprint. We'll discuss with you how best we can take forward your technology or research together

New avenues and opportunities

Shared passion to tackle agriculture's most complex challenges, increase innovation, and advance more sustainable agriculture

https://shootsbysyngenta.com/

Bringing plant potential to life