Reflections on directions for Plant Pathology

22nd September 2025

For the:

POLISH PHYTOPATHOLOGICAL SOCIETY

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Obsidian conference, Torun- 22/6-25

These reflections are currently being written up for the special issue of EJPP for the EFPP 2025 conference

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https://www.bspp.org.uk/

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DANSK SELSKAB FOR PLANTESYGDOMME OG SKADEDYR
DANISH SOCIETY FOR PLANT DISEASES AND PESTS


Potato


Elm


Coffee

Some serious "fungal" pathogens

- The **Oomycete** *Phytophthora infestans* caused the Potato famine 1840's (and led to the science of plantpathology)
  - https://www.bspp.org.uk/presidents-blog-potato-late-blight-is-where-it-started/
- *Bipolaris oryzae* (*Cochliobolus miyabeanus*) caused famine in Bengal in 1942
- Chestnut Blight caused by *Cryphonectria parasitica* killed billions of trees in the Eastern USA (and on sweet chestnut now Europe)
- *Hemileia vastatrix* wiped out the Coffee plantations of Sri Lanka in the 1870's and is now threating production in Latin America.
- Dutch Elm by *Ophiostoma* spp., especially *O. novo-ulmi*
- Dieback of ash caused by *Chalara fraxinea* emerged as recently 1992 as a lethal disease – cause ID in 2006
  https://bsppjournals.onlinelibrary.wiley.com/doi/10.1111/ppa.12196


Rice

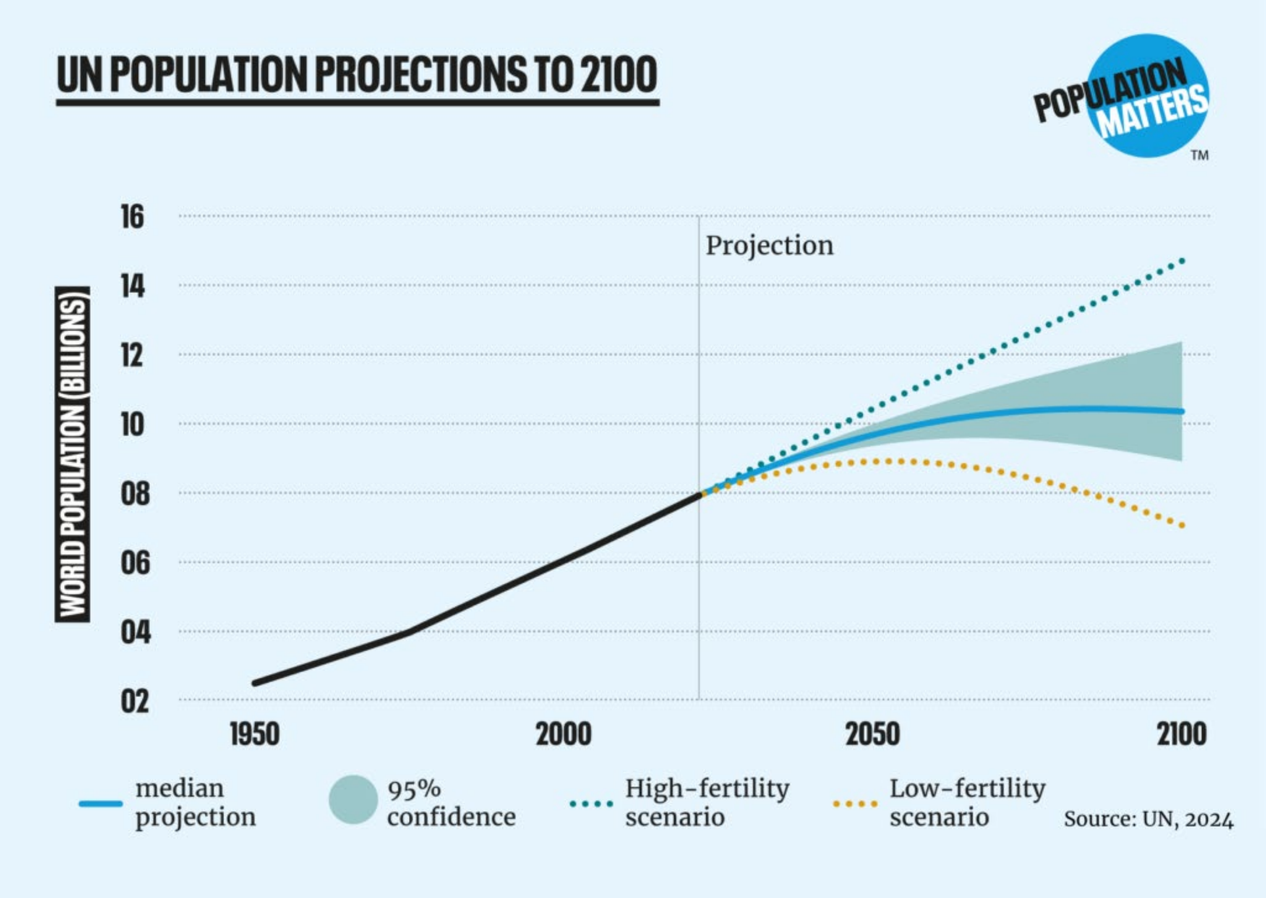

Ash

What is coming next?

Old foes will reemerge - like Late Blight on potato and Stem rust & Blast of cereals, banana wilt. And new unimagined threats

Plants are the source of virtually all food for humans

- The world's growing population, expected to approach 10 billion in 2050
- The population is more urbanised
    - And (still mostly) eats more meat
- Climate change means more unpredictable weather
- Increased global movements of plants, animals and people
  (COVID was just a glitch)
- Ample opportunity for, and probability that, plant pathogens will continue to spread



Starvation is not an issue in developed countries – yet

Combating plant diseases:

- Cultural practices
  - Irrigation, crop rotation, fertilisers etc
- Spraying with chemical agents:
  - Antimicrobial – *e.g.* Fungicides (Tilt®, copper)
  - 'Inducers' of the plant immunity (*e.g.* Bion®)
- Disease resistance
  - Screen for 'natural' resistance within the plant species/ closely related plant species
- Biotechnological
  - Biological control *i.e.* use of living antagonists
  - Achieve disease resistance through genetic engineering
  - New genomic technologies
    - Gene editing e.g. CRISPR

Threats

Stochastic climate

Pathogen resistance
Environment damage
Migration and mutation

Efficacy in field

Public opinion, efficacy

How can we improve their efficacy? We must!

Combating plant diseases – scenarios for future agriculture:

- Some scenarios may be sustainable but less appealing to farmers
  - due to lower income in a short time perspective
- Others may give a high net return in the short time but will be less sustainable.
- Farmers use crops that give a good net return.

  -> Monetary net return from a specific crop can be calculated easily

- Positive effects of other crop management actions,
  - maintaining good soil status
  - reducing overwintering populations of pathogens
  - (including those that are soilborne),

  -> Monetary returns are more difficult to calculate.

See *e.g.*, Chapter 22 in Tronsmo, et al 2020 Plant pathology and plant diseases. CABI, Wallingford. ISBN 9781789243178

Reduced tillage – reduces the carbon footprint

- Ploughing can
  - reduce the occurrence and magnitude of several plant diseases,
  - increase soil erosion.
- Reduced tillage saves
  - on fuel and soil moisture,
  - favours the survival of some pathogens
  - unfavourable for others,
  - often increases the use of fungicides and herbicides.
- **How can we balance** reducing the risk of soil erosion through reduced tillage and the need for ploughing to reduce the risk of, *e.g.,* mycotoxin contamination (caused by Fusarium head blight) in cereals?

FHB

P1P1

ML37

Water

Communicate the importance of plant diseases more clearly

- Governments (and also the public) take disease threats and consequences seriously.
- Increased interest in organic production results in lower levels of pesticide residues
  - and **perceived** increases in quality of food or feed.
- Urban people are distant to the realities of production of food, feed and fibre.
  - Threats to production are largely ignored by layfolk.
  - Increased awareness of human dependency on plants is critical for future food **security** and **sustainable** production on a global level.
- Recent massive campaigns to increase public awareness of risks from private import.

INTERNATIONAL YEAR OF PLANT HEALTH 2020

The theme for the 2021 EFPP meeting

Combating plant diseases for future agriculture:

What can be **predicted** is that, as weather becomes more **unpredictable**, so will the occurrences of acute diseases

The **acute diseases** will still need control measures,

- Since they will come in a sporadic manner,
    - The only strategy is to be prepared to deal with them quickly.

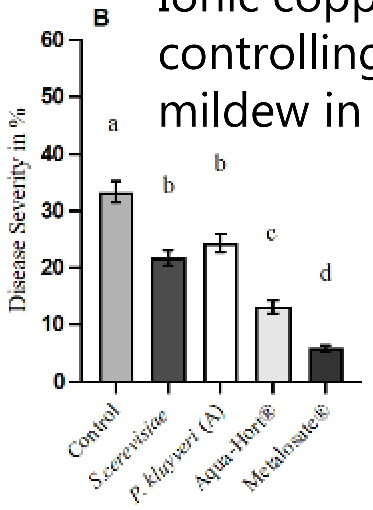
Chronic diseases might require a different strategy.

- The diseases that require constant attention and regular management activities.
- Monitoring needed – including diagnostics.
- Long-term, sustainable strategies, such as resistance breeding or management through different cultural practices.
- Examples include leaf blotch diseases in wheat caused by *e.g.*, *Zymoseptoria tritici, Parastagonospora nodorum* and *Pyrenophora tritici-repentis*.
- The leaf blotch diseases are very rarely absent, and when cultural practices are not sufficient, they are managed with fungicides.

Text book stuff! *e.g.,* Tronsmo AM, Collinge DB, Djurle A, Munk L, Yuen J and Tronsmo A 2020 Plant pathology and plant diseases. CABI, Wallingford. ISBN 9781789243178

Late blight of potato and tomato caused by *Phytophthora infestans*

- Evolves rapidly
- Biological control?
- Transgenic approaches? Cisgenic – moving genes from related species
- New “fungicides” *e.g.*, Mandipropamid, Propamocarb active against oomycetes – exhibit different modes of action
- Ionic copper (Aqua-Hort®)?



Ionic copper controlling downy mildew in grape

Race-specific resistance in potato 1970s
(Photo © V. Smedegaard)

MSc project 2022 Rikke Adelsten Behrendt

Behrendt et al (2024). Wine Yeast as Potential Biological Control Agent Against Downy Mildew of Grapevine (*Plasmopara viticola*). Proc. 21st International Conference on Organic Fruit-Growing, Filderstadt 2024.02.19-21. Ed. FOEKO e.V. 2024: 51-57

Gene silencing

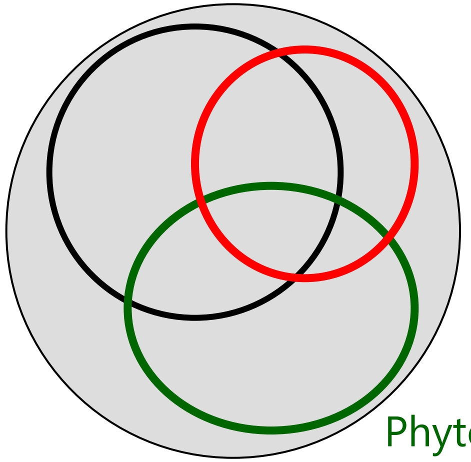
- Viral disease control by gene silencing has been very successful for several crops
- Host-induced gene silencing is demonstrated for various nematodes and several pathogens, including the fusarium head blight complex in cereals and for *F. odoratissimum* in banana

Collinge & Sarrocco (2022) Plant Pathology 71: 207–225. DOI: 10.1111/ppa.13443

Specialised metabolites (often called secondary metabolites)

- Fungi produce specialised metabolites for many reasons, many obscure.
- An important reason is to provide a competitive advantage in the environment in interactions with other organisms
  - Potential predators (*e.g.,* mites that feed on fungi)
  - Potential substrates (*i.e.* plants that fight back – defend themselves)
  - Competitors in the environment (*i.e.* other microbes)

- **Mycotoxins** affect both humans and livestock



Phytotoxins damage plants

Mycotoxins damage *e.g.,* mammals

We don't often know why they make them: grey zone.

Mycotoxins are specialised metabolites capable of causing disease and death in humans and other animals

Mycotoxins *e.g.*, Fumonisin in Fusarium-contaminated maize feed has poisoned this American horse

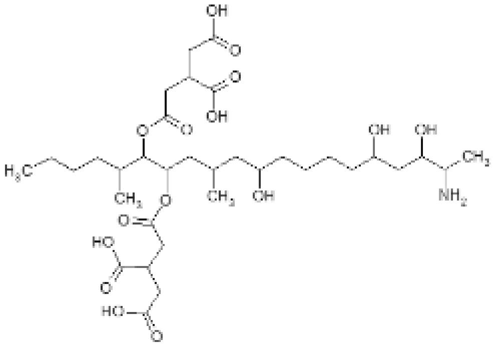
This is also a serious problem in fodder in Europe.

Maximum limits of mycotoxin content in food and feed (EU)

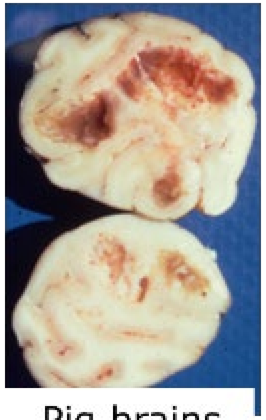
Some allowed levels are very close to the chemical detection limits (trichothecenes HT-2 and T-2)

BT (GMO) maize can contain lower mycotoxin levels where corn-borers are a problem

Maize also has problems with aflatoxins (*Aspergillus flavus*)



Fumonisin (Ulf Trane, DTU)
Produced by *Fusarium verticillioides*



Pig brains

Mycotoxins

- Most important sources
  - *Aspergillus*
  - *Fusarium*
  - *Penicillium*
  - *Claviceps*

Aspergillus ear rot of corn

Caused by zearalenone

- Many diverse chemical structures and physiological effects on mammals include:
  - Hormonal effects (oestrogen mimics)
  - Carcinogenic
  - Acutely toxic

- Some produced by many species

- Many are heat stable and some can accumulate in milk, beer and other products – fermentation helps!

Ergot in wheat

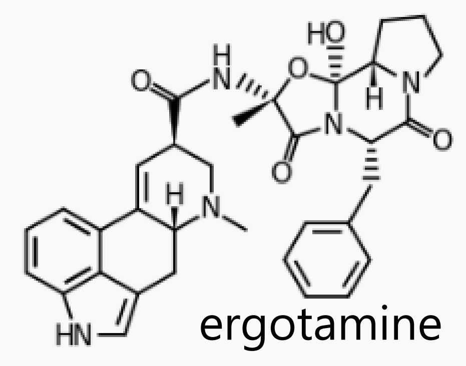
St Anthony's fire (1512–1516)

Example – Ergotism

- Caused by an Ascomycete: *Claviceps purpurea*
- Infects *e.g.*, barley, wheat and rye, and is not unknown in organic rye. The dry gangrene is a result of vasoconstriction induced by the ergotamine-ergocristine alkaloids of the fungus.
- “Saint Anthony's fire” – *ergotisme*
- Ergot alkaloids have pharmaceutical use for vasoconstriction and migraines. Also, as a recreational drug.
- … **used** to be controlled by seed treatment with fungicides

Danish Veterinary and Food Administration
Fødevarestyrelsens laboratorium, Ringsted

Saint Anthony's fire



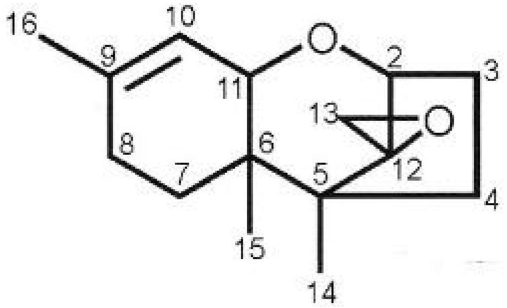
Ergot (*meldrøjer*) on rye (*rug*). Lolland, July 2024

Example: Fusarium spp

- At least 30 spp. of Fusarium produce mycotoxins among many different specialised metabolites

- The most important classes recognised at present are:
  - Tricothecenes
  - Fumonisins
  - Zearalenone

- But there are more "emerging toxins"
  - Not new, just recently discovered.



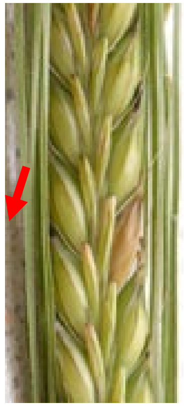
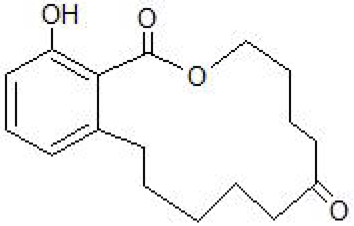
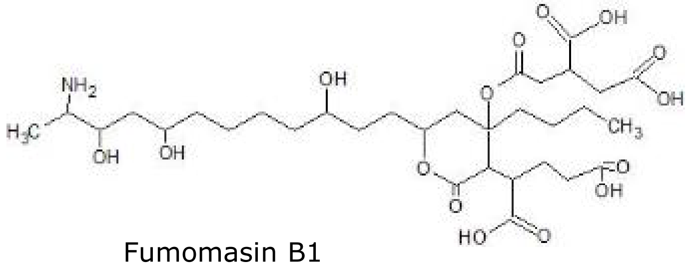


Figure 1. Structure of trichothecenes.

Includes DON - deoxynivalenol



Zearalenone



Fumomasin B1

- A.E. Desjardins (2006) Fusarium mycotoxins APS Press
- Petrucci et al (2024) submitted to CABI Plant Health Cases

Some FHB *Fusarium* spp and their toxins

affecting temperate small grain cereals

(species co-occurrence in a sample is frequent)

Table 1. Fusarium head blight species complex list.

Species	Species complex	Host	Trichothecenes	Polyketides and non-ribosomal peptides	Salt	Additional plant disease	Distribution
Fusarium graminearum (Giberella zeae telom.)	FGSC	barley, oat, rye, wheat	NIV, DON, 3-ADON, 15-ADON	ZEN		FSB	North America, Europe
Fusarium acaciae-mearnsii	FGSC	*Acacia mearnsii*, soil	NIV, 3-ADON				Australia, South Africa
Fusarium aethiopicum	FGSC	wheat	15-ADON				Ethiopia
Fusarium asiaticum	FGSC	barley, maize, oat, rice wheat,	NIV, 3-ADON, 15-ADON				Asia (China, Nepal, Japan, Korea), America (Brazil, USA)
Fusarium austroamericanum	FGSC	herbaceous vine, maize	NIV, 3-ADON				Brazil, Venezuela
Fusarium boothii	FGSC	maize	15-ADON				South Africa, Mexico, Guatemala, Nepal, Korea, USA
Fusarium brasilicum	FGSC	barley, oat	NIV, 3-ADON				Brazil
Fusarium cotaderiae	FGSC	*Cortadeira sellona*, carnation, barley, maize, wheat, soil	NIV, 3-ADON				Argentina, Brazil, Australia, New Zealand
Fusarium gerlachi	FGSC	giant cane, wheat	NIV				USA
Fusarium louisianese	FGSC	wheat	NIV				USA
Fusarium meridionale	FGSC	barley stem, maize, orange twig, wheat, soil	NIV				Brazil, Guatemala, South Africa, Australia, New Caledonia, Nepal, Korea, USA
Fusarium mesoamericanum	FGSC	banana, grape, ivy	NIV, 3-ADON				Honduras, USA
Fusarium nepalese	FGSC	rice	15-ADON				Nepal
Fusarium ussarium	FGSC	oat, wheat	3-ADON				Far East Russia
Fusarium vorosii	FGSC	Wheat	15-ADON				Japan, Hungary
Fusarium avenacenum	FTSC	barley, oat, rye, wheat		BEA, ENs	MON	FCR, FSB	Worldwide
Fusarium tricinctum	FTSC	barley, wheat	T-2	ENs	MON	FCR	Temperate region all over the world
Fusarium culmorum		barley, oat, rye, wheat	DON	ZEN		FCR, FSB	North Europe
Fusarium langsethiae		barley, oat, rye, wheat	T-2, HT-2 and DAS				North, and West Europe, North-western and Central Russia
Fusarium poae		barley, oat, rye, wheat	T-2, HT-2 and DAS			FCR	North America, Northen and Central Europe, Asia (China, Russia and Japan)
Fusarium pseudograminearum		barley, wheat	NIV and DON	ZEN		FCR	Australia, South America
Fusarium sporotrichioides		barley, oat, wheat	T-2, HT-2 and DAS				North, East Europe
Fusarium cerealis		barley, wheat	NIV, 4-ANIV	ZEN		FCR, FSB	North America, Europe, China, Australia, New Zealand, Russia
Microdochium majus		grass, rye, wheat				FSB	North America
Microdochium nivale		grass, rye, wheat					Norway

Species: all species currently known to be related to FHB. Species complex: FGSC = Fusarium graminearum species complex; FTSC = Fusarium tricinctum species complex. Host: Plant hosts. Trichothecenes: Type A: T-2, HT-2 and DAS = diacetoxyscirpentriol; Type B: DON= deoxynivalenol, 3-ADON = 3-acetyldeoxynivalenol, 15-ADON = 15-acetyldeoxynivalenol, NIV = nivalenol and 4-ANIV = 4-acetylnivalenol, Polyketides and non-ribosomal peptides: ZEN = Zearaleanone, BEA = beauvericin and ENs= enniatins. Salt: MON = moniliformin (Additional plant disease: many of the species here included are more often linked to disease other than FHB, namely FCR = Fusarium crown rot, FSB = Fusarium Seedling blight. Distribution: Species' main geographical areas.

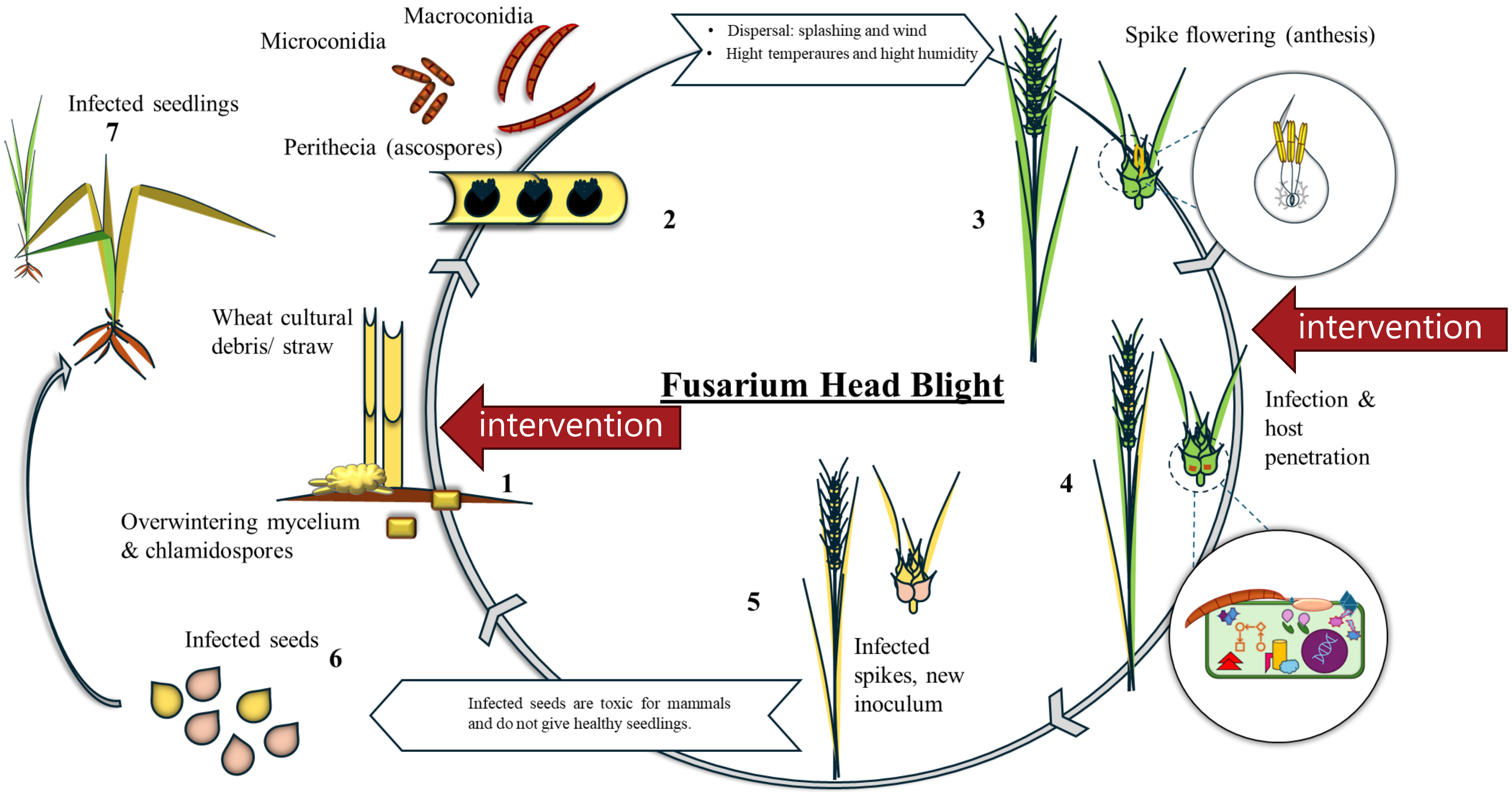
DON – deoxynivalenol
NIV – nivalenol
ADON – acetylated DON
ZEA – zearalenone
HT2 & T2 – type 1 trichothecenes

There are also little-known compounds like Culmorin

Take home message:
it's complicated

Petrucci A, Sarrocco S, Jensen B, Collinge DB (2025) Biological control of Fusarium head blight in cereals: insights into molecular interactions within the pathosystem. CABI Plant Health Cases DOI: 10.1079/planthealthcases.2025.0004

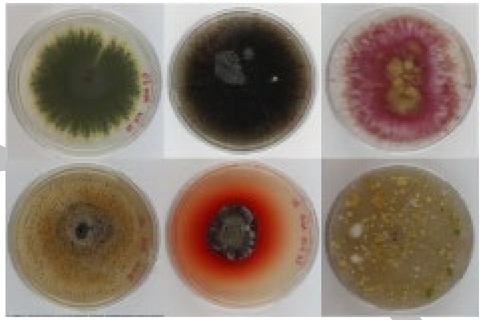
Disease cycle for Fusarium-wheat interactions



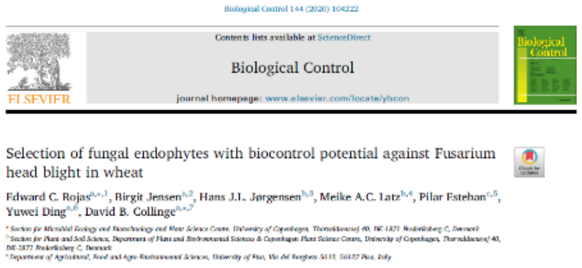
Petrucci et al. (2025) CABI Plant Health Cases DOI: 10.1079/planthealthcases.2025.0004

Screening for fungal biocontrol agents for Fusarium and Septoria diseases in cereals

Sampling &
Isolation from healthy plants in the field where there is disease pressure



Identification & colonisation efficiency



Biological Control 144 (2020) 104222

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Selection of fungal endophytes with biocontrol potential against Fusarium head blight in wheat

Edward C. Rojas[a,*,1], Birgit Jensen[b,2], Hans J.L. Jørgensen[b,3], Meike A.C. Latz[b,4], Pilar Esteban[c,5], Yuwei Ding[a,6], David B. Collinge[a,*,7]

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Biological Control 141 (2020) 104128

Contents lists available at ScienceDirect

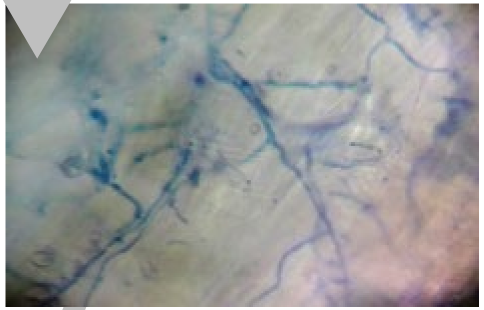
Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Identification of two endophytic fungi that control Septoria tritici blotch in the field, using a structured screening approach

Meike A.C. Latz[*,1], Birgit Jensen[2], David B. Collinge[3], Hans Jørgen Lyngs Jørgensen[4]

Department of Plant and Environmental Sciences and Copenhagen Plant Science Centre, University of Copenhagen, DK-1871 Frederiksberg C, Denmark



Inoculate wheat plants with potential fungal BCA to test for biocontrol activity against Septoria or Fusarium spp. under controlled conditions

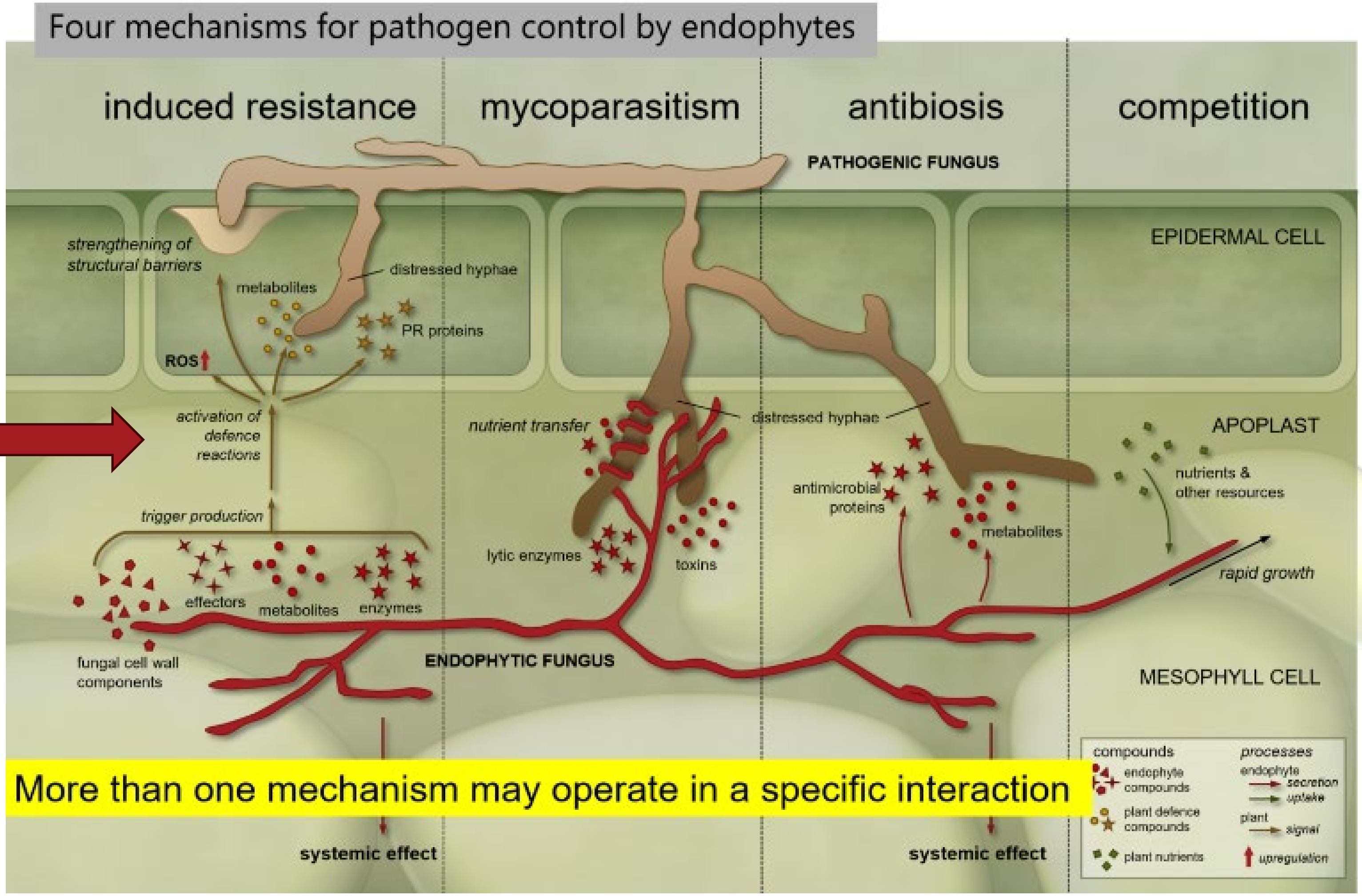
To field trials

Collinge et al (2019). Searching for novel fungal biological control agents for plant disease control among endophytes. In Hodkinson et al https://doi.org/10.1017/9781108607667.003

Four mechanisms for pathogen control by endophytes

Plant defence mechanisms, or immunity!

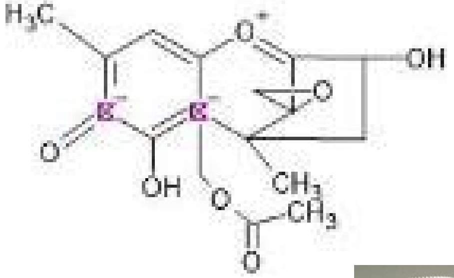
This is why you should avoid screening for BCAs in Petri dish confrontation tests



© Latz, et al (2018) Plant Ecology & Diversity 11, 555–567
doi.org/10.1080/17550874.2018.1534146

Fusarium Head blight is even more tricky to control in oat (*Avena sativa*) that wheat (*Triticum aestivum*)

- The flowering is extended: infection occurs over a longer period
- Diagnostics is difficult – outward symptoms resemble senescence
- Few sources of resistance



- Is FHB in oat a candidate for biological control?
- Can we detoxify trichothecene mycotoxins?

A barley UGT HvUGT13248 overexpressed in wheat shown previously* to
- increase tolerance to deoxynivalenol (DON) and nivalenol (NIV)
- decrease disease the severity of both Fusarium head blight and Fusarium crown rot.

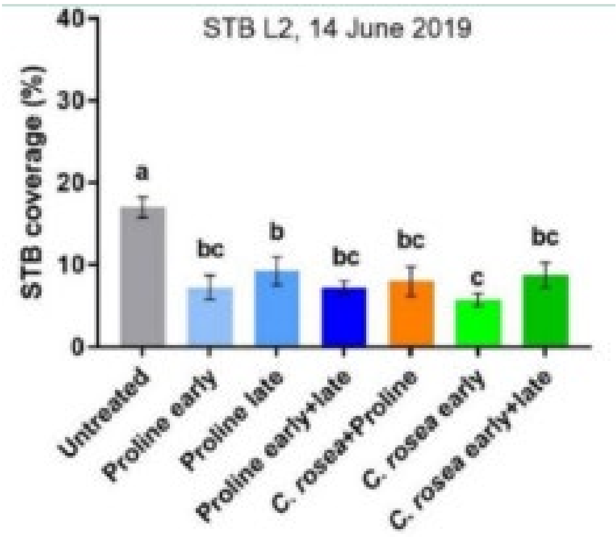
The two oat UGTs could therefore play an important role in counteracting the Fusarium virulence factor DON in oat.

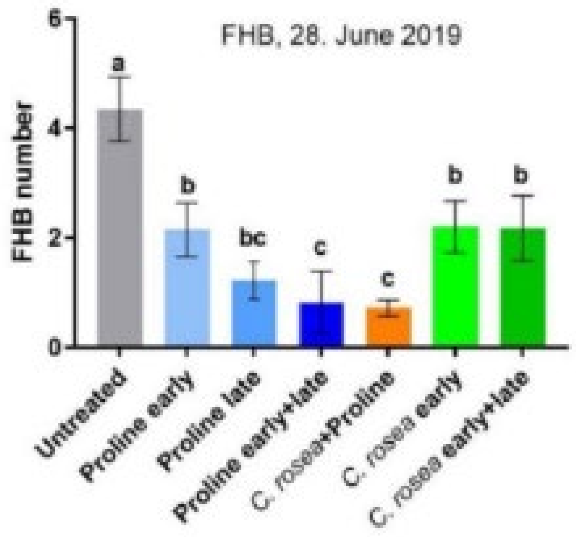
*Li et al. at BOKU (2017). JXB 68: 2187-2197.

Khairullina *in prep* & Khairullina (2022) *Toxins,* 14, 446. DOI: https://doi.org/10.3390/toxins14070446

Can we combine fungicide treatment with biological control?

Effect of *C. rosea* +/- Proline® on Septoria tritici blight & Fusarium head blight in the field





STB (*Zymoseptoria tritici*)

Yes! It **can** be as effective as a fungicide and they can be combined in the field. With reduced DON.

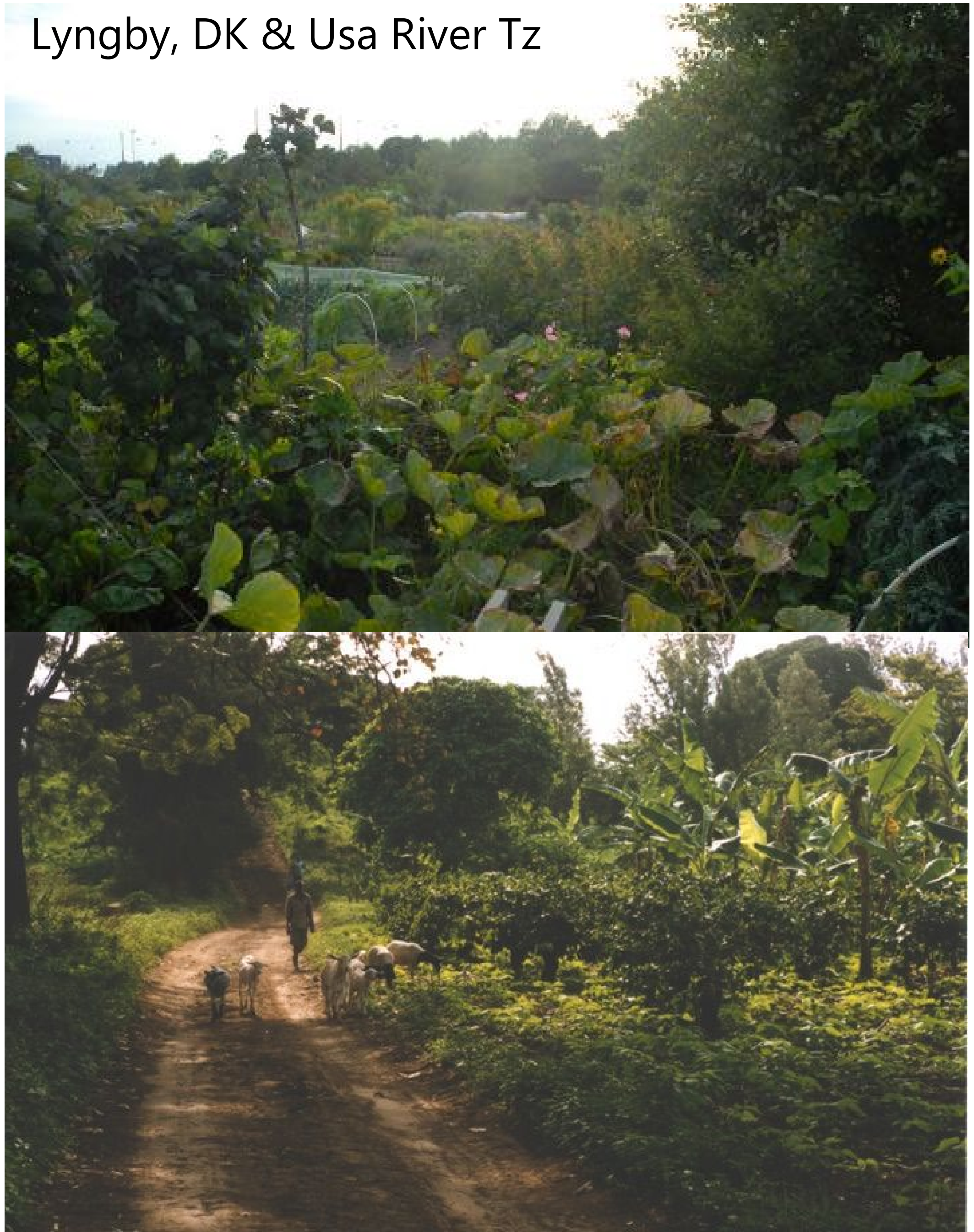
FHB

Jensen et al 2022 Microbial biocontrol agents in IPM strategies. (Funding: The Danish Environmental Protection Agency)

Variety mixtures, intercropping and agroforestry

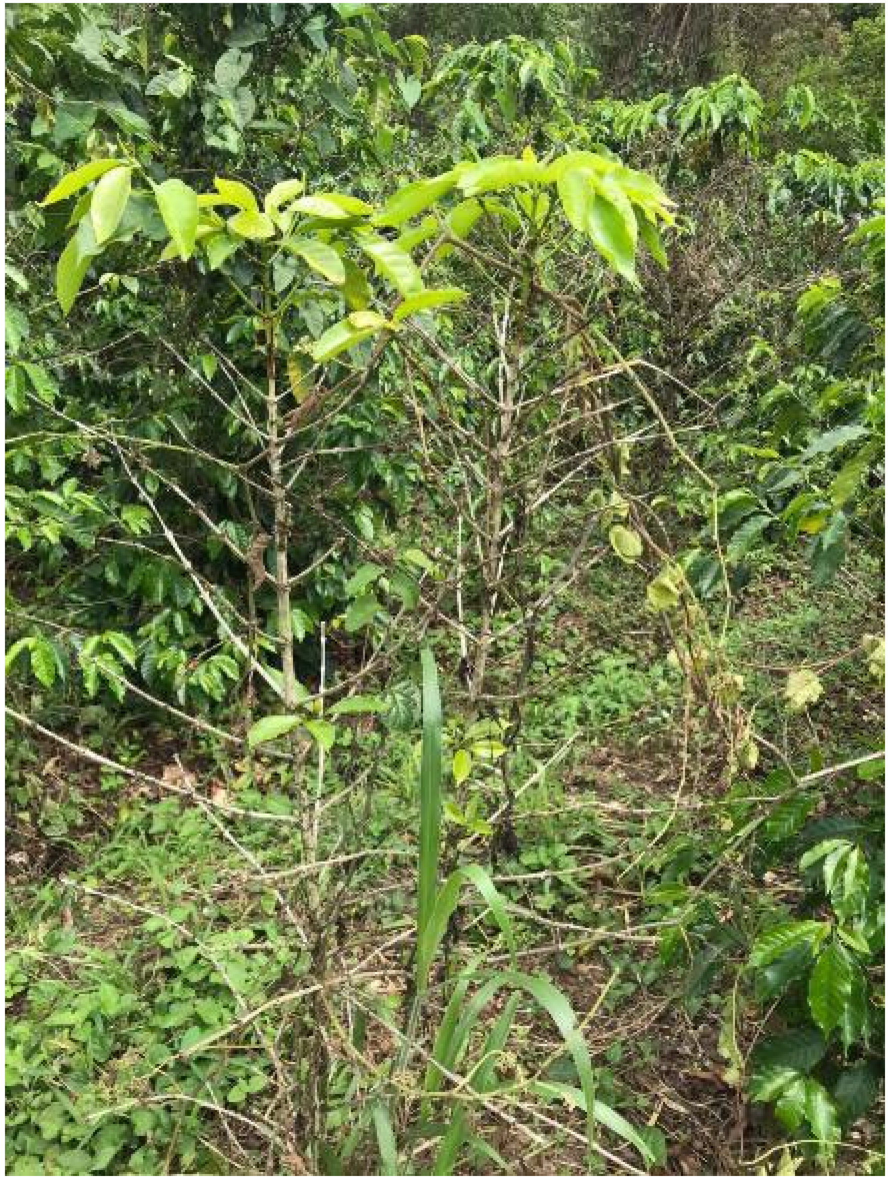
- Effective ecological approaches to plant disease management.
- They can stimulate soil biodiversity and provide a more diverse microbiome including more beneficial microorganisms.
- Slows the epidemic development of many diseases will be slowed down. Diversification strategies also results in yield stability and better exploitation of nutrients.

Koutouleas A, Collinge DB, Ræbild A (2023). Plant Pathology 72: 409-429, https://doi.org/10.1111/ppa.13676



Integrated pest management (IPM)

- IPM aims to reduce the use of pesticides in crop production.
- Requires **better predictive systems** suitable tools for managing the diseases.
- Successful IPM programme also requires an understanding on how day-to-day decisions are made by growers in relation to crop production and pest management.
- Part of this challenge is to understand how decision makers balance short-term gains with the longer-term benefits for the agricultural systems that they manage.



Plant pathology research is a snapshot of **all** science

- As a community, we exploit biology, physics, chemistry, mathematics and engineering to understand the interactions between microbes, plants and the environment
  - nobody can understand all of it!
- Talks at recent conferences (*e.g.*, ICPP2023 in Lyon, EFPP2025 in Uppsala) have covered the state-of-the-art ranging from fundamental biology and forecasting to providing real practical solutions for managing diseases and plagues.
- Senior scientists from most of the world have presented their complex state of the art research so we can all follow
  - Presenting hypotheses rather than just collecting data (fishing trips).
- We can see especially how well younger scientists – and students – are making real contributions.

Beyond Linnaeus!

Directions for Plant Pathology

- Our subject is in safe hands, but we need to be political and awake to make sure that resources are provided to solve the increasing challenges faced.
- Communication is the key…
- EFSA has the campaign PlantHealth4Life
  - https://www.efsa.europa.eu/en/plh4l/year-3-planthealth4life-empowers-citizens-become-plant-health-ambassadors
  - " *When citizens understand the vital role of plant health in their lives — from the food on their tables to the air they breathe — they become powerful agents of change,"* explains Sylvain Giraud

National societies are important catalytic tools – **be active**!

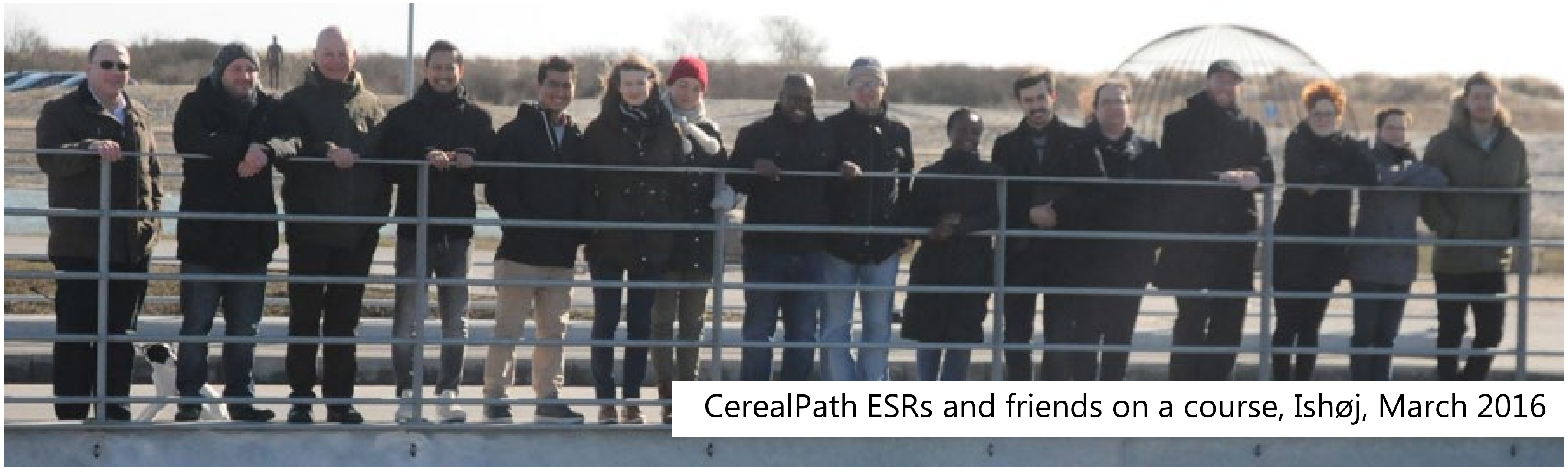
EFPP European Foundation for Plant Pathology
https://www.efpp.net/societies.htm

BSPP

DSPS

Svensk växtpatologisk förening
Swedish Society for Plant Pathology

Edward Rojas and Meike Latz were supported by CerealPath which received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 674964 (cerealpath.eu)


CerealPath ESRs and friends on a course, Ishøj, March 2016

Also thanks to Lise Nistrup Jørgensen AU. Dan Funck Jensen, & Magnus Karlsson, SLU, Uppsala

Ministry of Environment and Gender Equality
Environmental Protection Agency

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Alfia Khairullina defended her thesis 29th Sept 2023 at Lund

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Choose a well-defined topic in plant pathology that includes research with a quantifiable outcome. Final manuscripts have 2000 - 4000 words plus images, figures and tables.

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- Collinge & Sarrocco (2022) Plant Pathology 71: 207–225. https://bsppjournals.onlinelibrary.wiley.com/doi/full/10.1111/ppa.13443
- Collinge *et al.* (2022) Current Opinion in Microbiology 69: 102177 https://doi.org/10.1016/j.mib.2022.102177
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