INRAE

OHID
One Health International Days
2024 June 27 & 28

Moulds and mycotoxins along the cereal value chain: from plant health to human health

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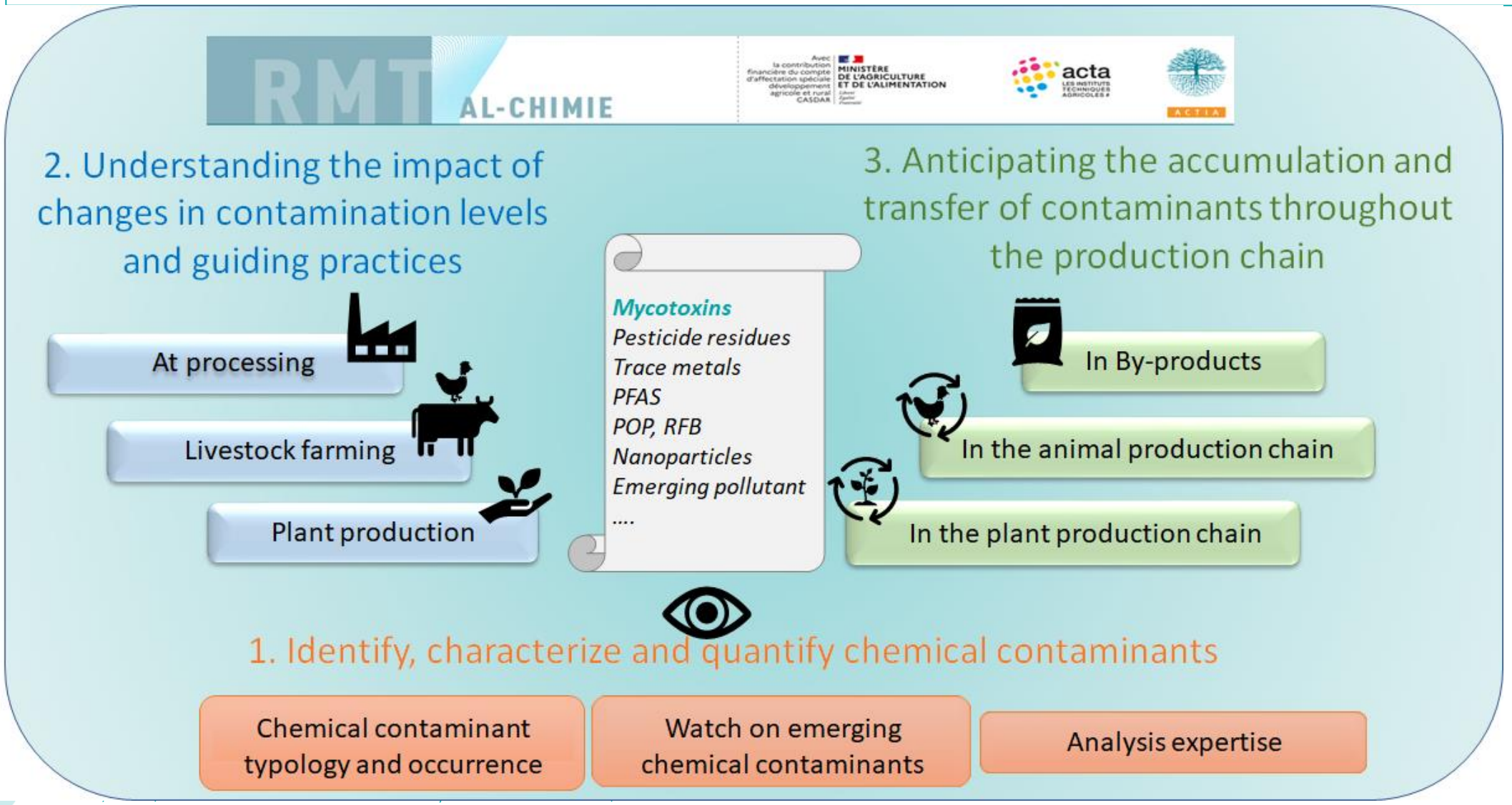
MycSA UR1264 Mycologie et Sécurité des aliments INRAE

https://mycsa.bordeaux-aquitaine.hub.inrae.fr/

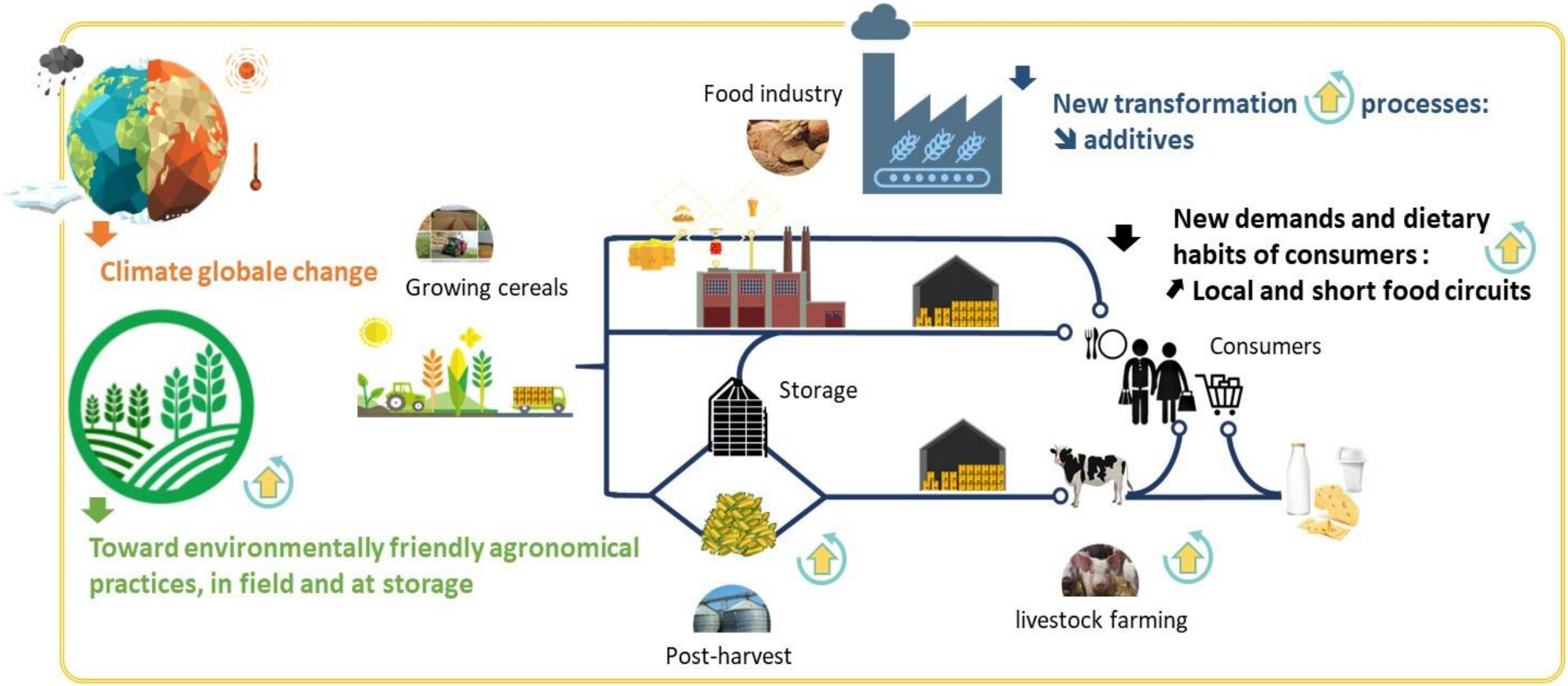
One health : preserving the food chains from chemical contaminants

One health : preserving the food chains from chemical contaminants

A network : R&D – multi-sectors = Chemical contaminations in the food chains

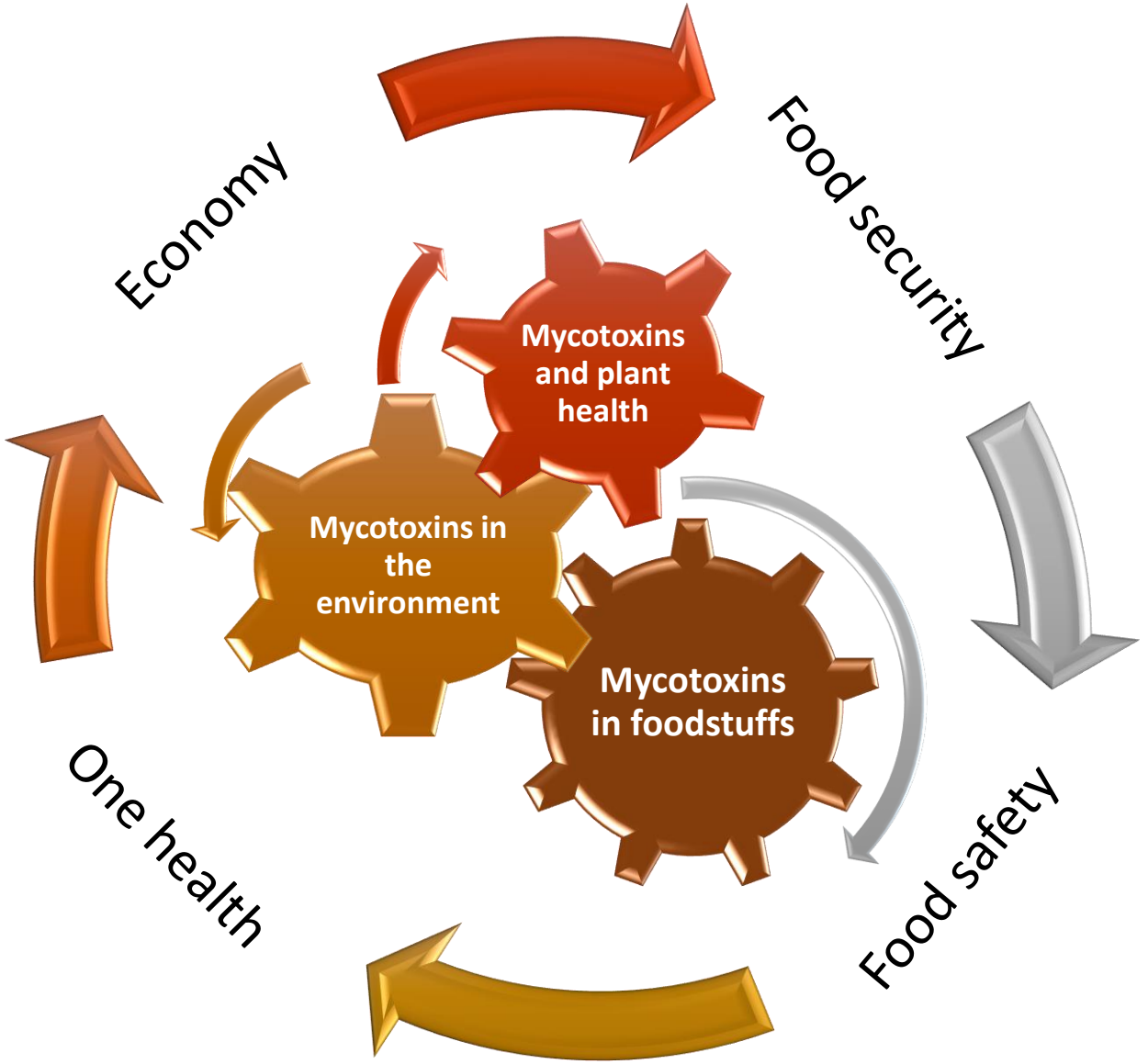


The cereal food chain under global changes



Mycotoxins

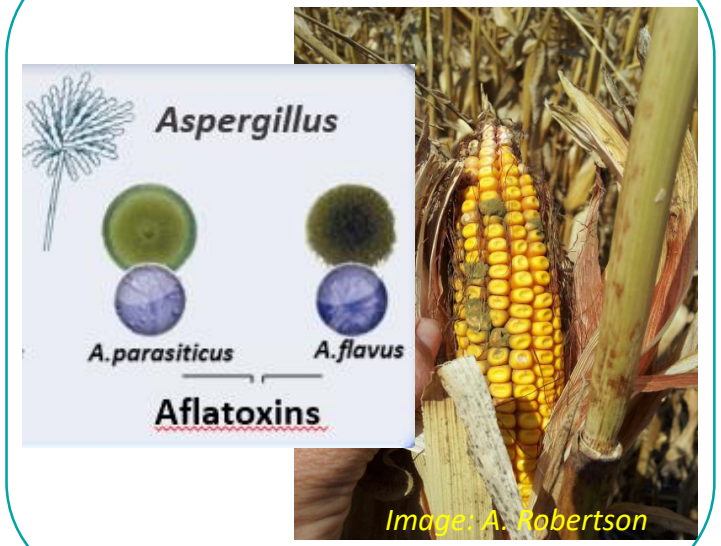
Mycotoxins are secondary metabolites produced by (phyto-)pathogenic fungi, which are potent toxins having severe health consequences in people.



- ✓ Different fungal genus : *Fusarium, Aspergillus, Penicillium, Alternaria,* etc…
- ✓ A mycotoxin can be produced by several fungal species.
- ✓ A fungal species can produce several mycotoxins
- ✓ Intraspecific variability in the ability to produce mycotoxins.
- ✓ A diversity of chemical structures.
- ✓ Diversity of effects and cellular targets.

European Commission "**mycotoxin contamination results in annual global crop losses of 5 to 10%"** (EC, 2015)
=> € 1.2-2.4 billions of lost income for cereals (*Focker et al 2021)*

Mycotoxins issues / Plant health

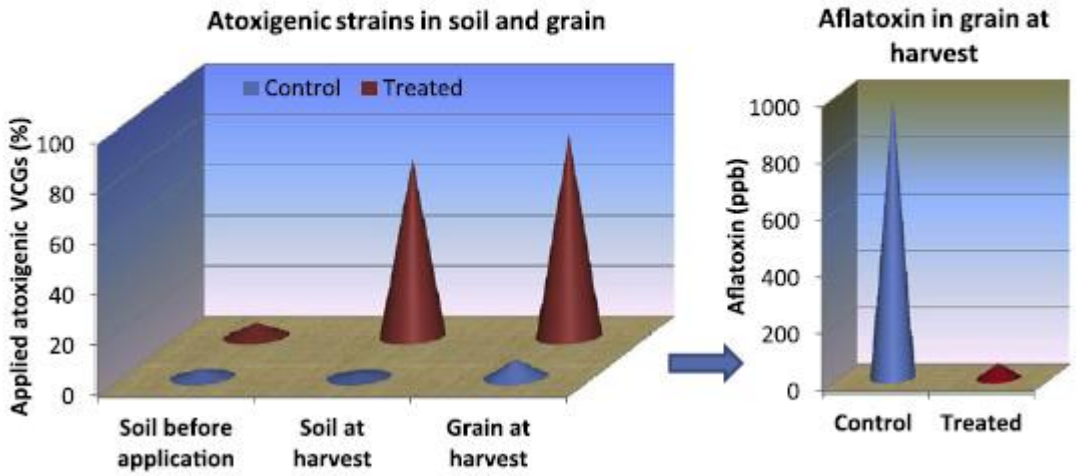


Global Change and Emerging issues

No varietal resistance or chemical control of ergot. Influenced by the evolution in agricultural practices, including:

- ✓ Less control through ploughing with the general shift to low or non-tillage systems
- ✓ Blackgrass remains widespread and acts as a significant host for the disease
- ✓ Grain rye is increasing as a crop and is particularly susceptible
- ✓ Spring wheat is more affected than winter types due to its more open flowering habit
- ✓ Grass margins can increase disease where early flowering grass species are used
- ✓ The incidence of the disease is affected by weather conditions during flowering: cool, dull, and wet weather tends to increase spore production, prolongs flowering and increases secondary tillering, which can all lead to higher levels of infection.

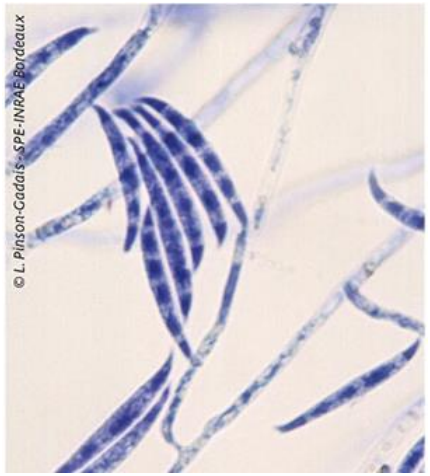
Increased proportion of applied atoxigenic strains in soil and grains translates into reduced aflatoxin concentration in grain

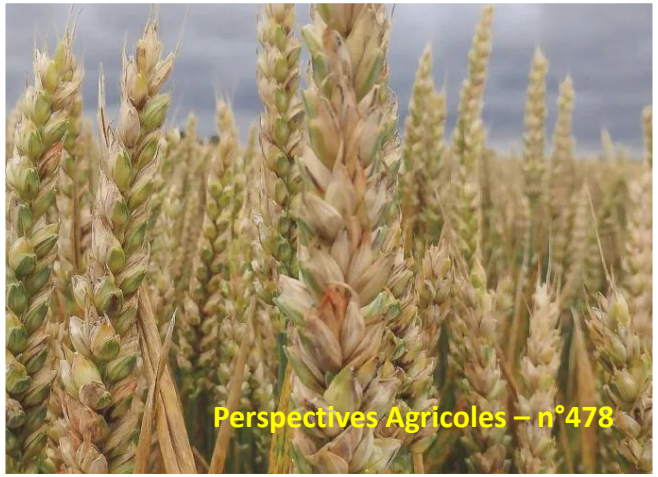


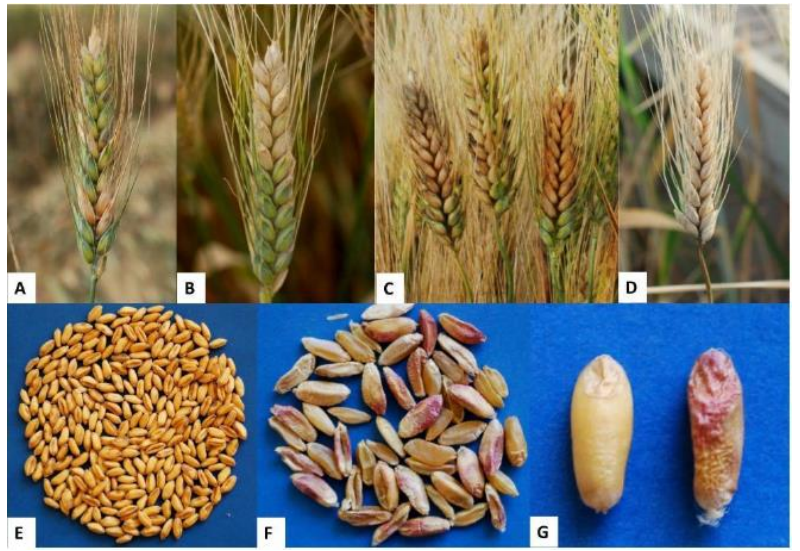
Atehnkeng et al, Biological Control 2014, 72, 62-70

Mycotoxins issues / Plant health

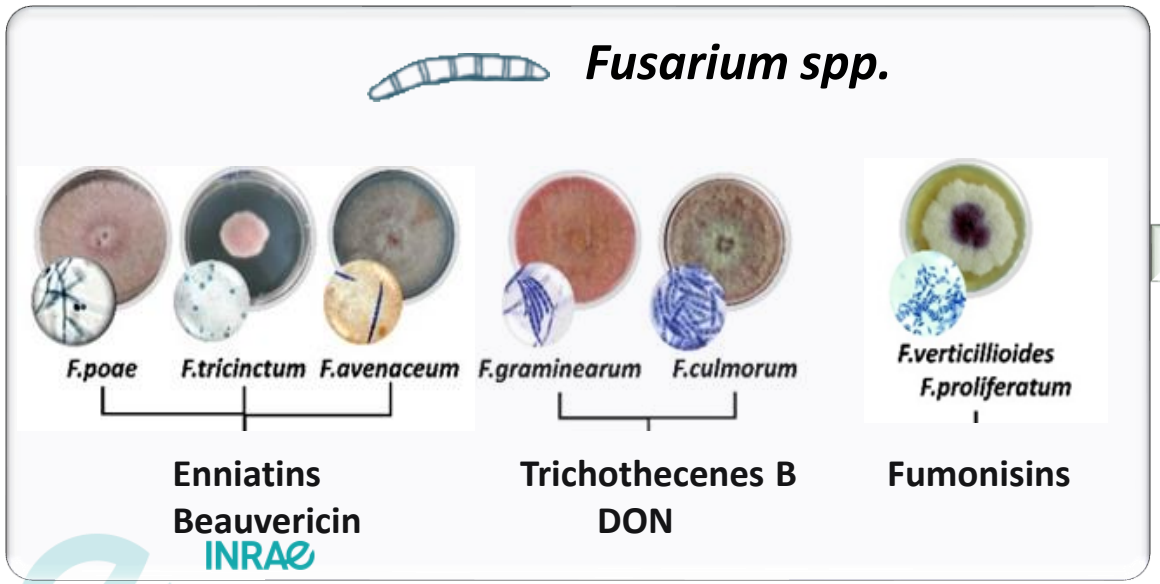
Fusarium Head Blight







Wiem Chtioui, et al. 2022 - Toxins. 14. 10.3390



Fusarium Head blight (FHB)

Fusarium Ear Rot

Mycotoxins issues / Plant health

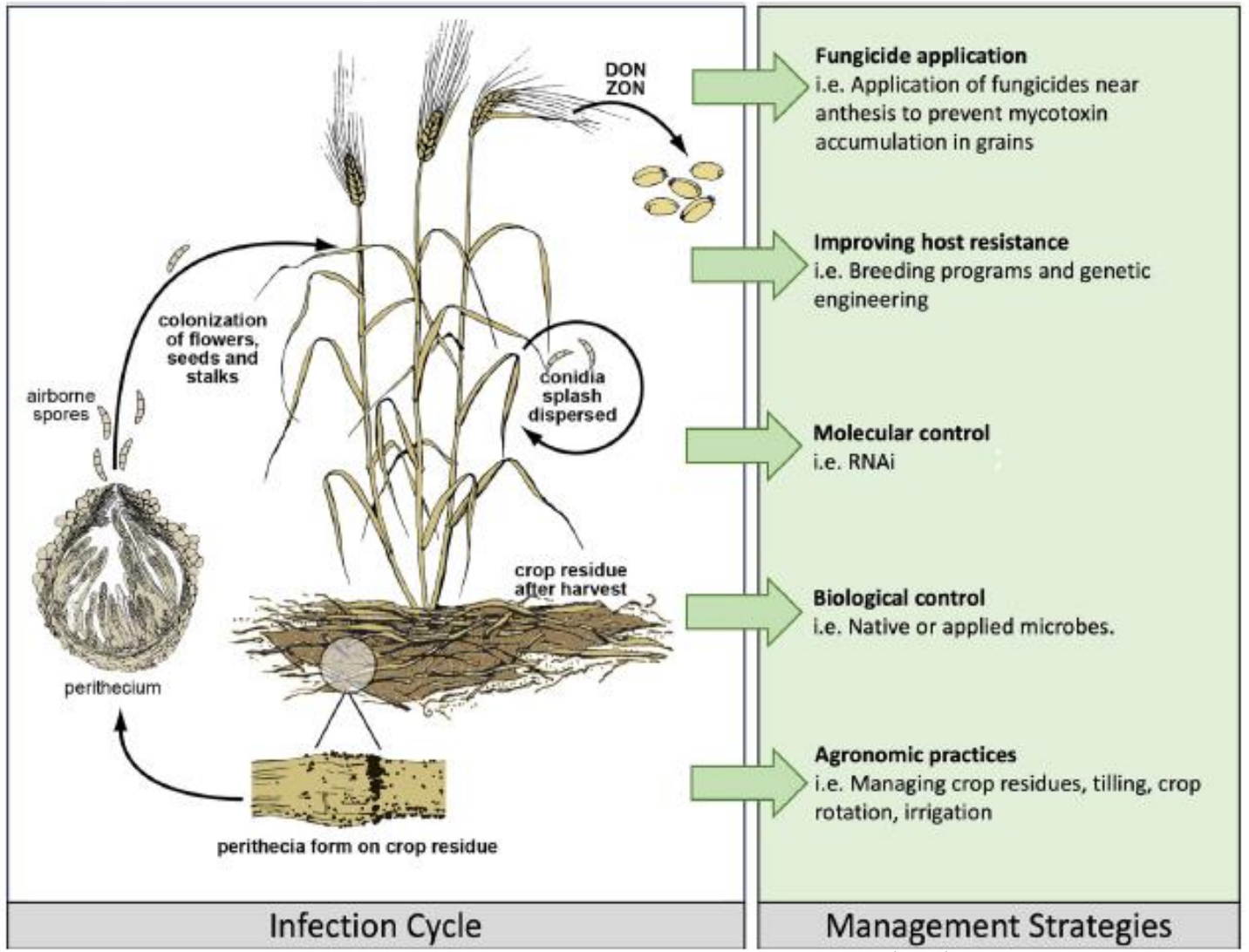
Fusarium Head Blight

1- infection during anthesis and colonization of internal tissues

2- Spreading to adjacent florets, the entire head, and the rachis through

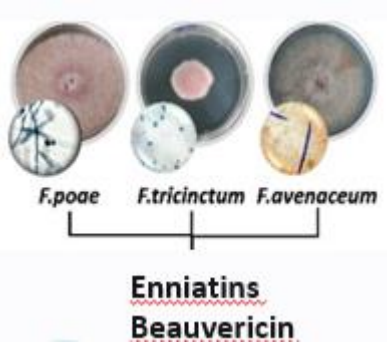
Zhang et al. BMC Microbiology (2015) 15:35

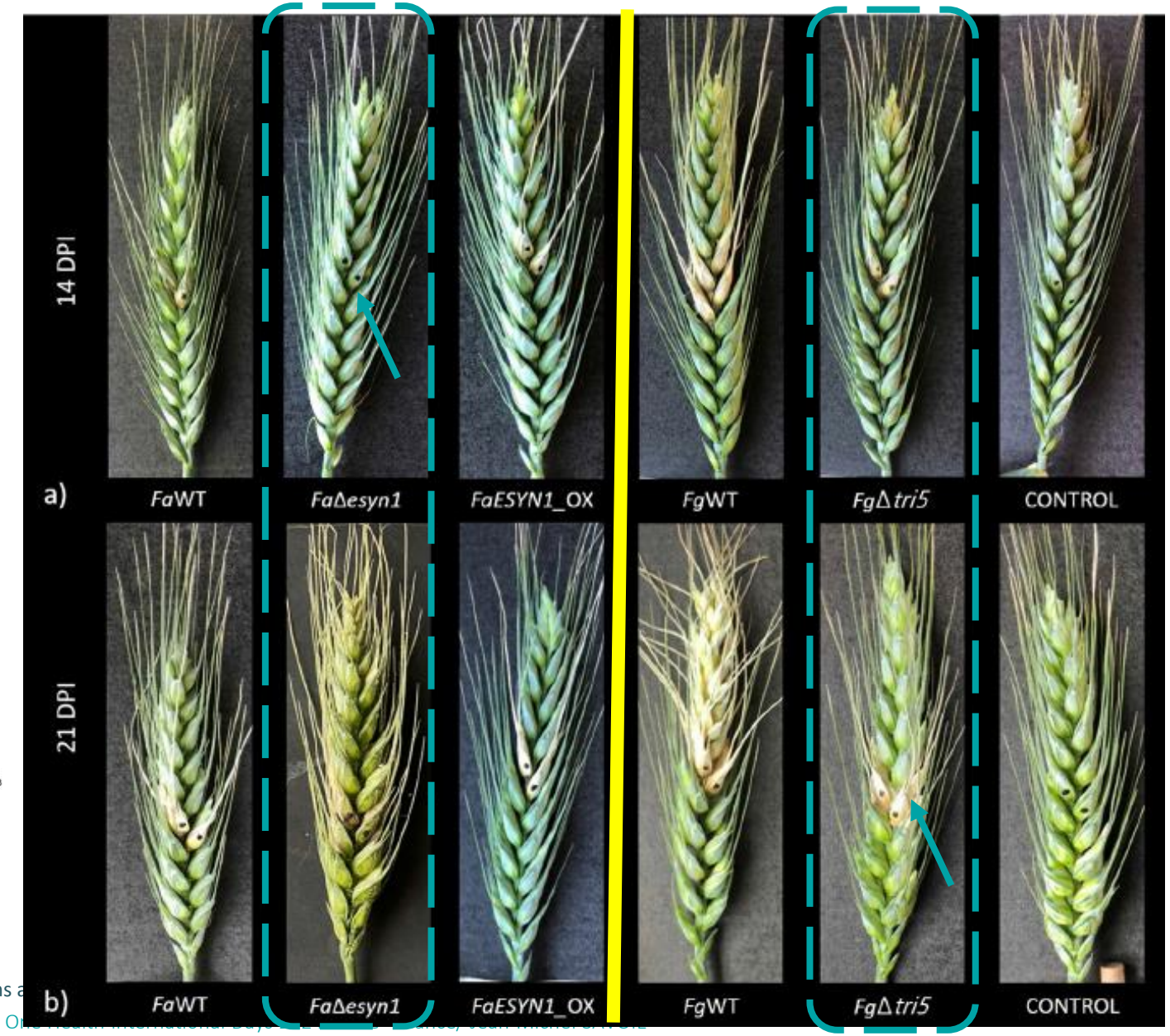
3- overwintering on colonized crop residues,
4- fruiting bodies development under under favourable environmental conditions,
5- Go back to 1-

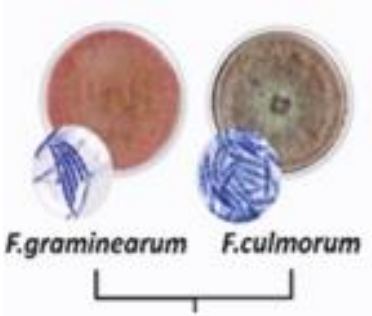


S. Moonjely et al. Fungal Genetics and Biology 169 (2023) 103829

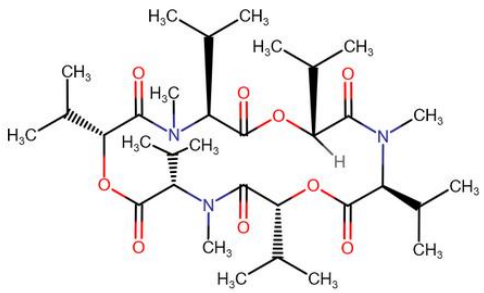
Mycotoxins issues / Plant health





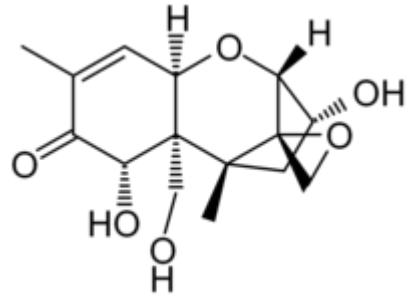


Contribution of enniatins to fungal virulence



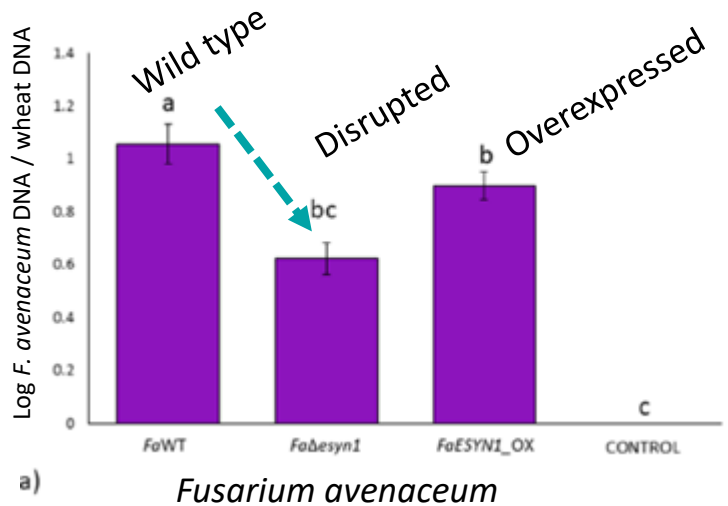
Enniatin B

The trichothecene B, DON is a known fungal virulence factor

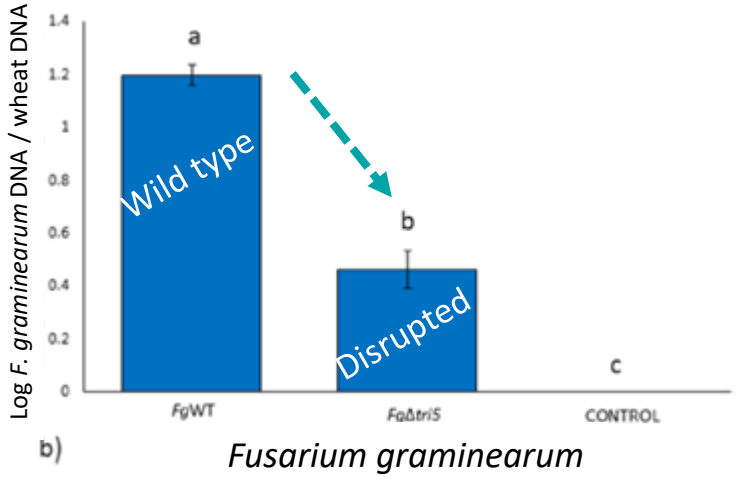


Beccari et al. BMC Plant Biology (2024) 24:463

Mycotoxins issues / Plant health



Fusarium avenaceum



Fusarium graminearum

Fungal biomass accumulation in wheat heads at 28 dpi

Secondary metabolites		*F. avenaceum* strain		
		FaWT	*FaΔesyn1*	*FaESYN1_OX*
Total enniatins	ng g^{-1}	6060	< LOD	3310
	SE	993	< LOD	719
	MCT	a	c	b

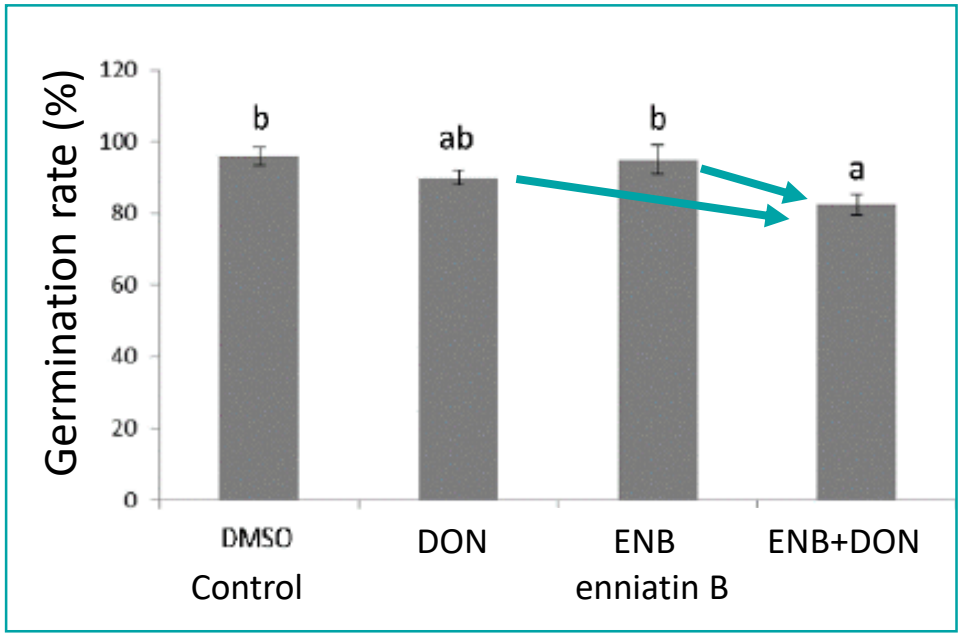
LOD (Limit Of Detection)

Secondary metabolites		*F. graminearum* strains	
		FgWT	*FgΔtri5*
Total deoxynivalenol	ng g^{-1}	32,100	< LOD
	SE	6680	< LOD
	MCT	a	b

Mycotoxins in wheat heads at 28 dpi

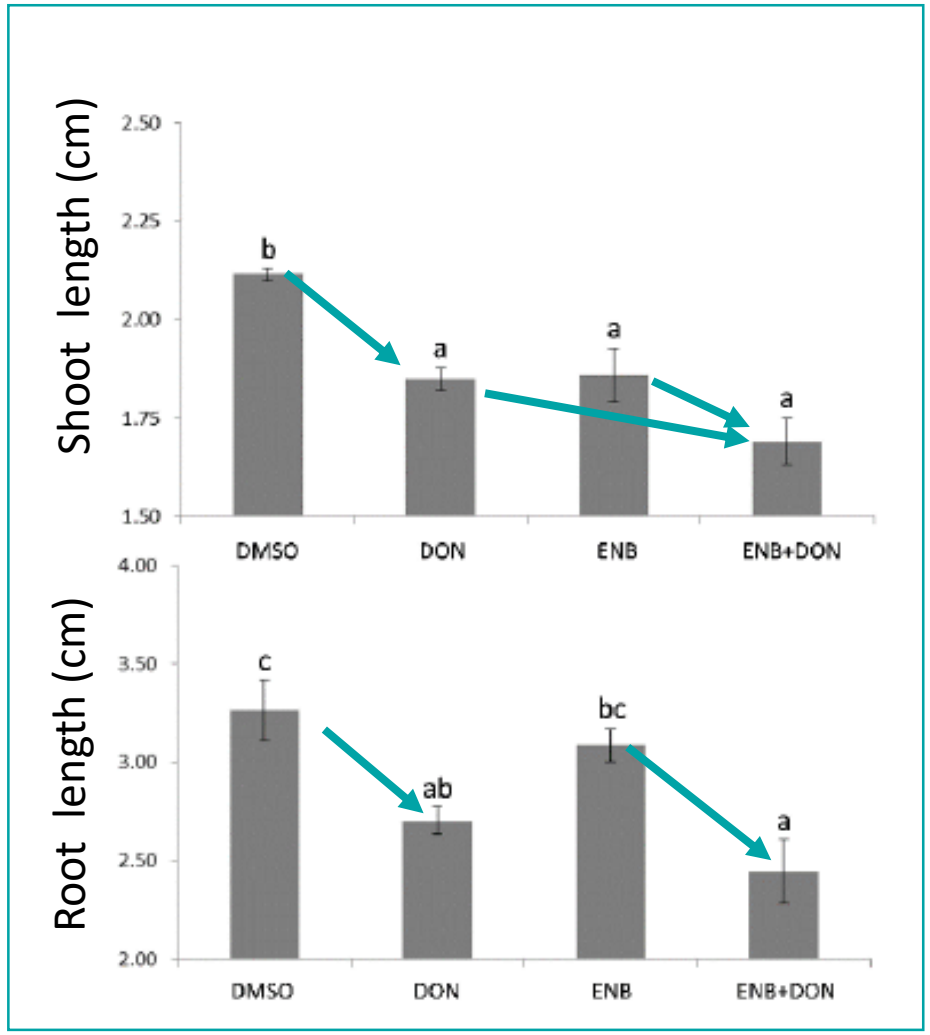
Beccari et al. BMC Plant Biology (2024) 24:463

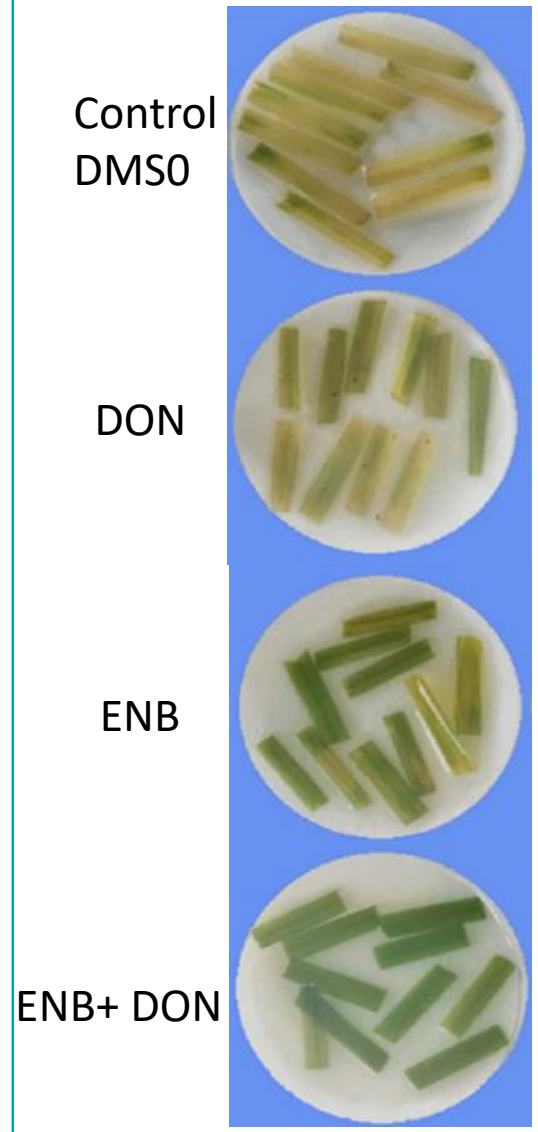
Mycotoxins issues / Plant health **Phytotoxicity**



Seeds incubated for 24 h in a solution of mycotoxin (10 mg/kg)

Vigour measured after 4 days





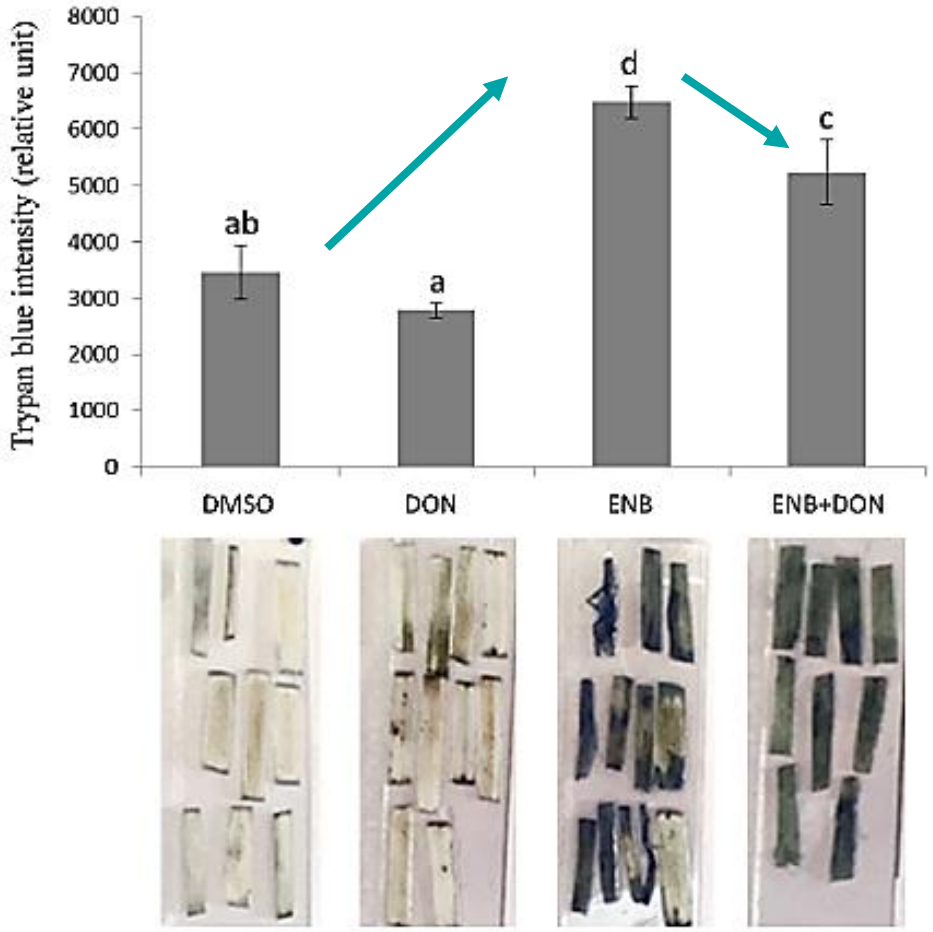
Change in pigment content
7 days post treatment

Ederli et al. Toxins 2021;13(10):728.

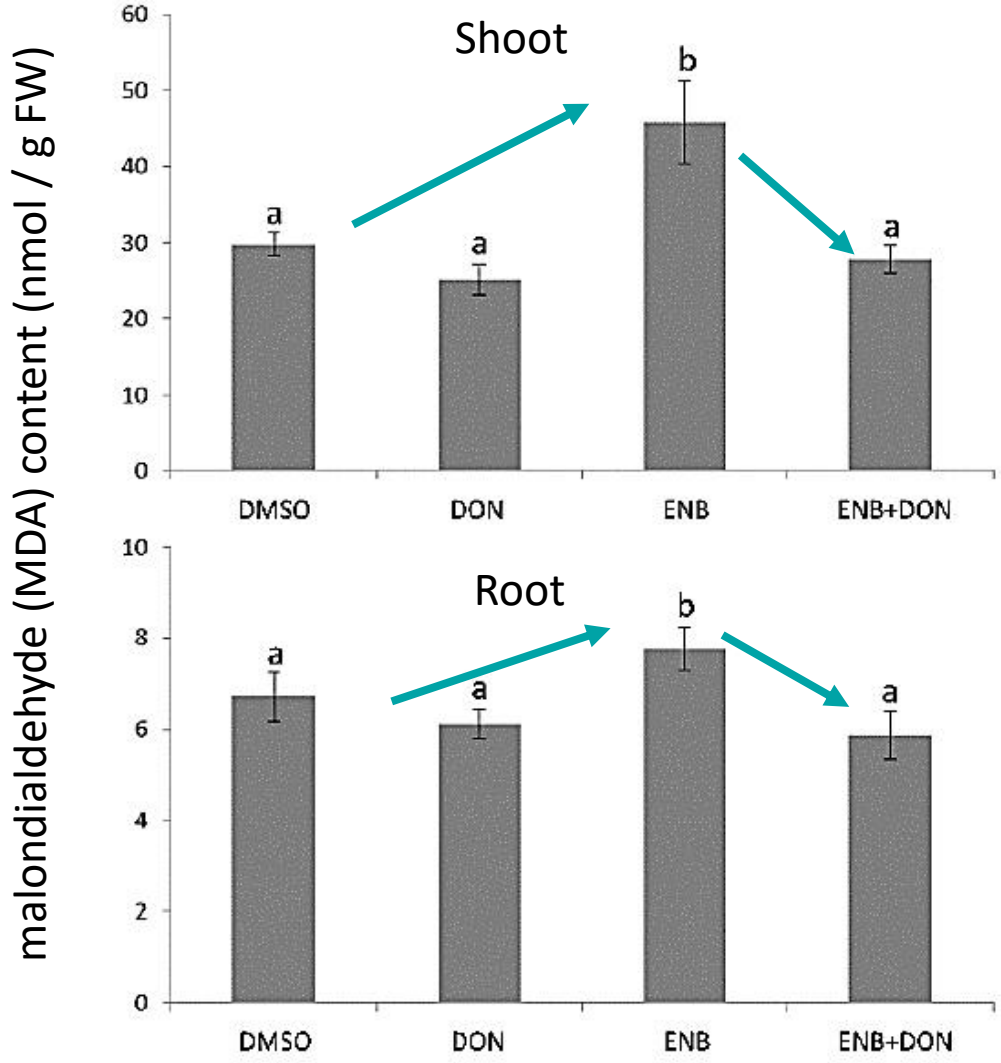
Mycotoxins issues / Plant health

Phytotoxicity

Cell death / trypan blue staining



oxidative stress



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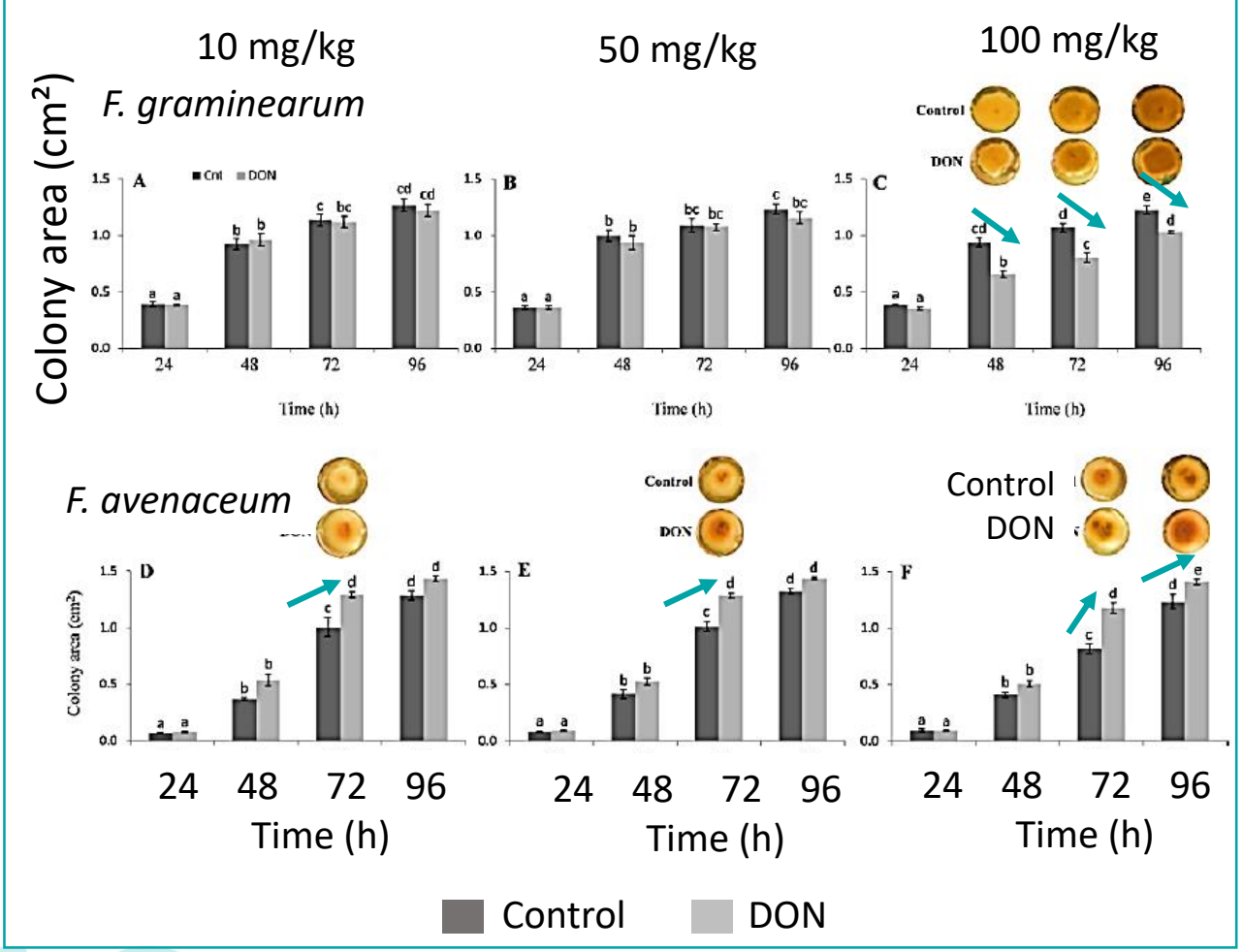
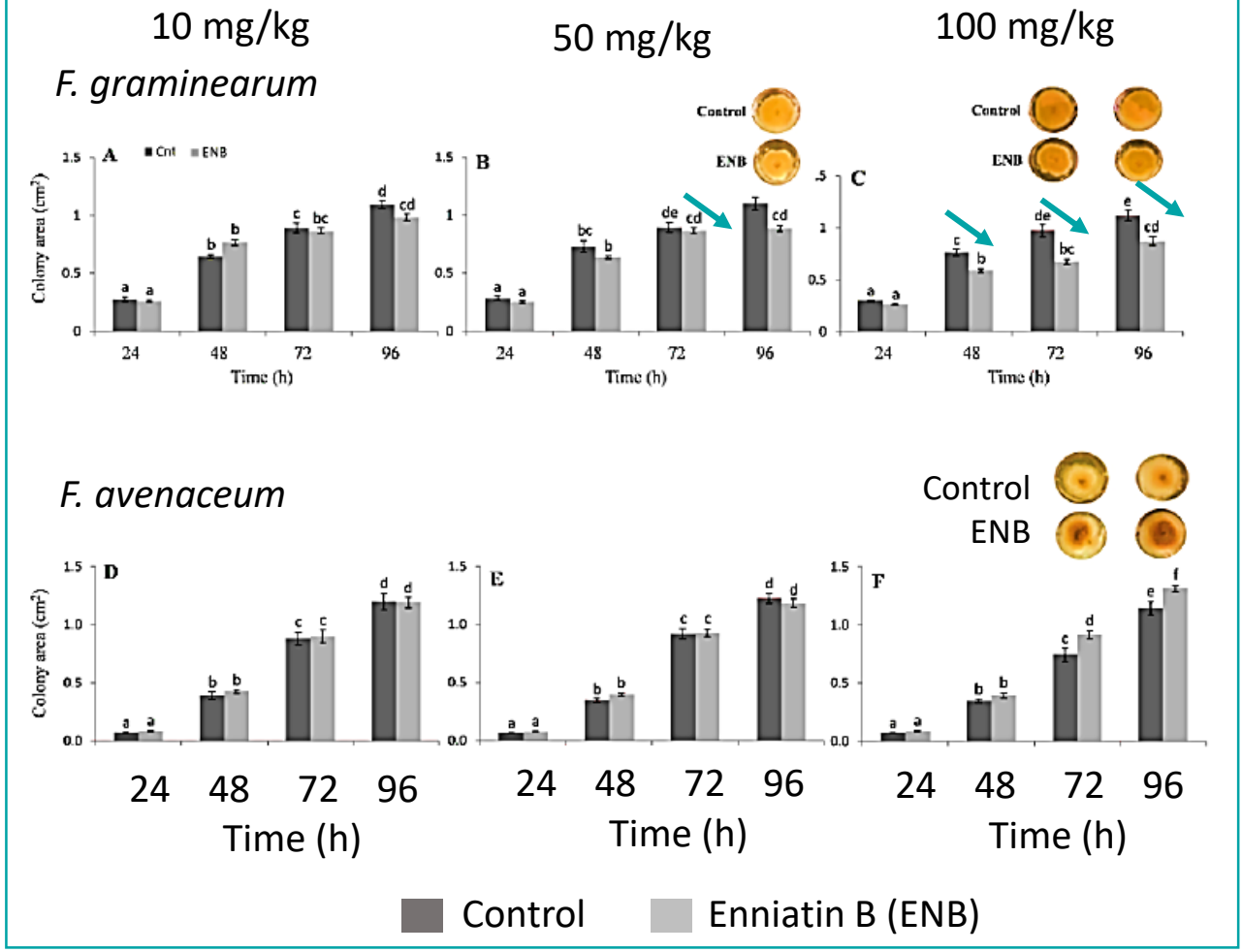
Mycotoxins issues / Plant health

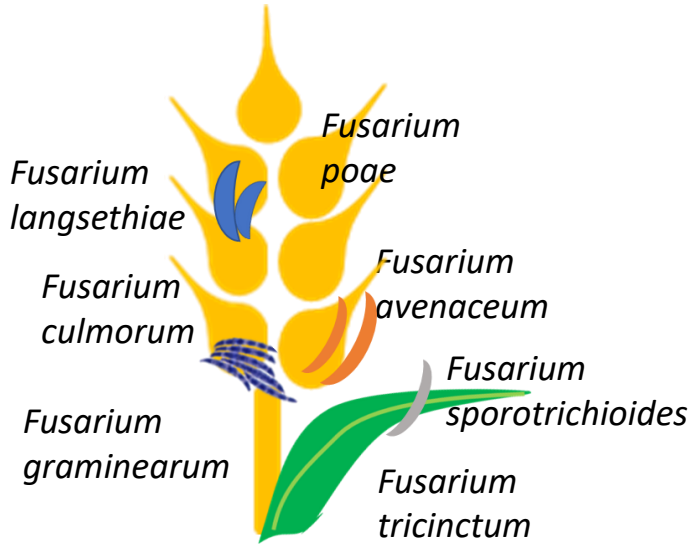
Mycotoxicity



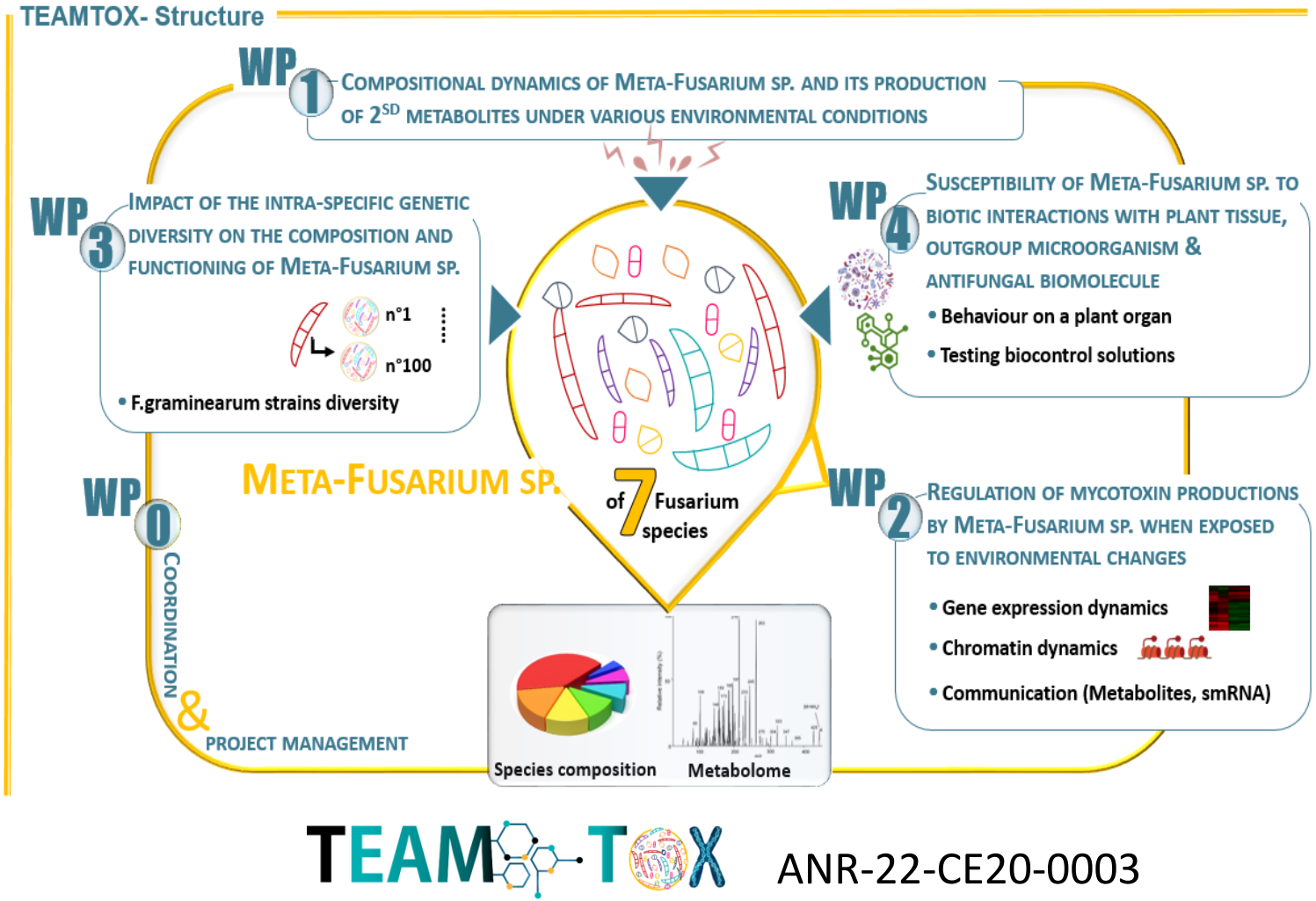


Beccari et al. BMC Plant Biology (2024) 24:463

Mycotoxins issues / Plant health – Multispecies competition



Paradigm shift = Meta-Fusarium



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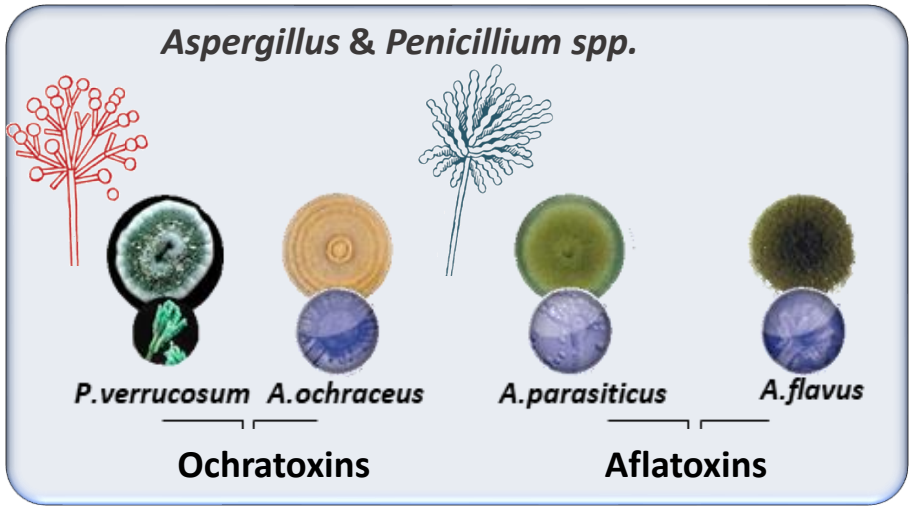
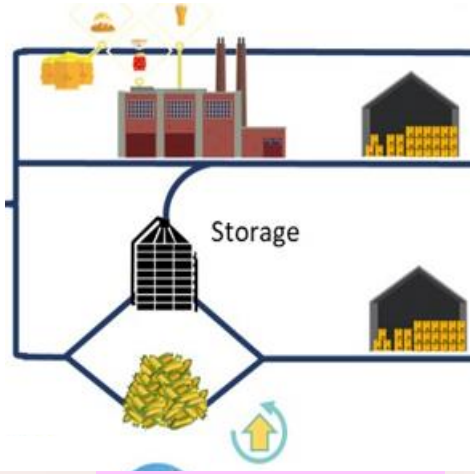
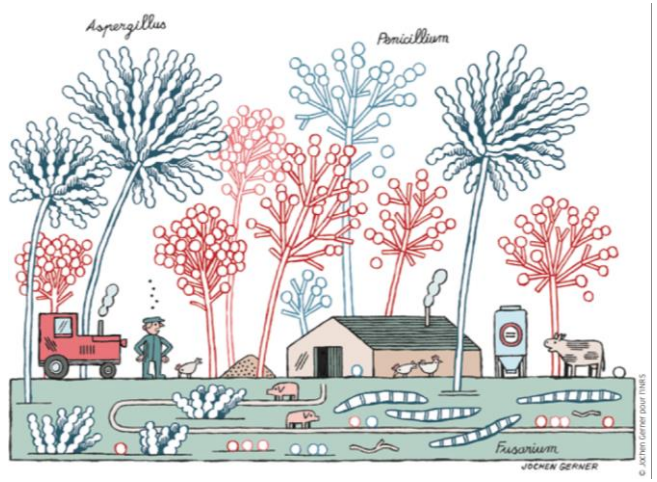
Mycotoxins issues / Plant health - Storage

Post harvest development of mycotoxinogenic fungi



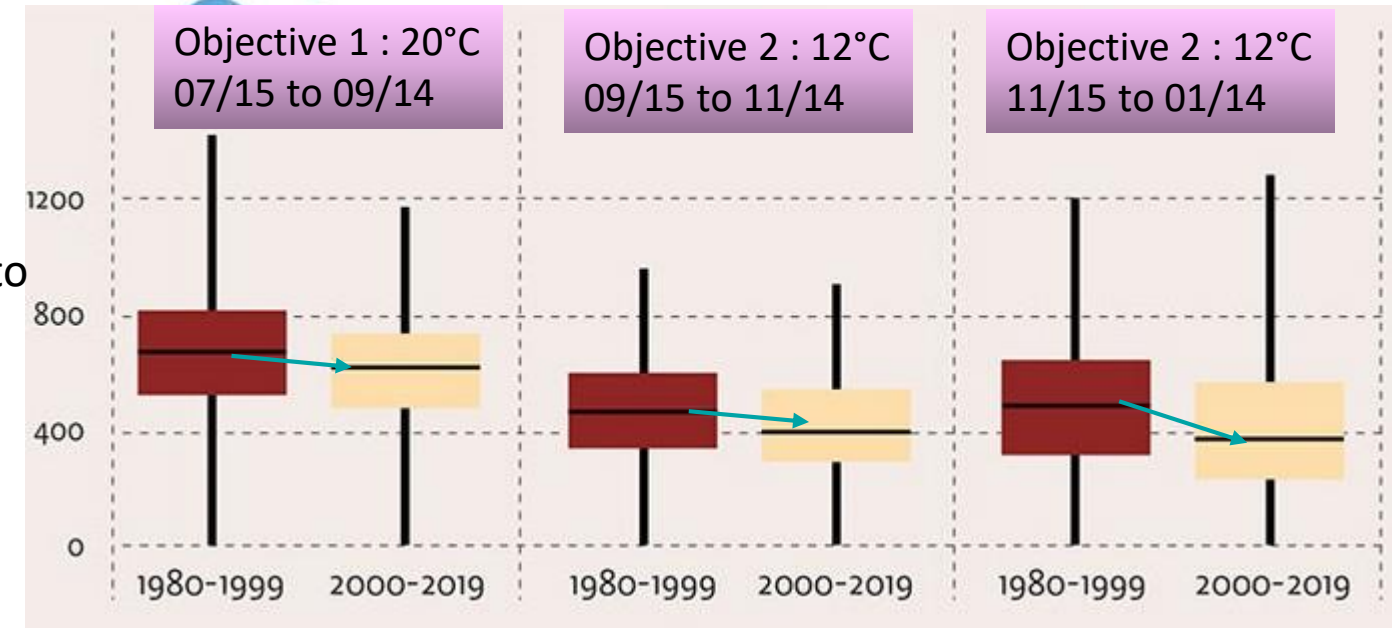
Storage





Hours favourable to cooling objectives

In 2050 :
1/3 less



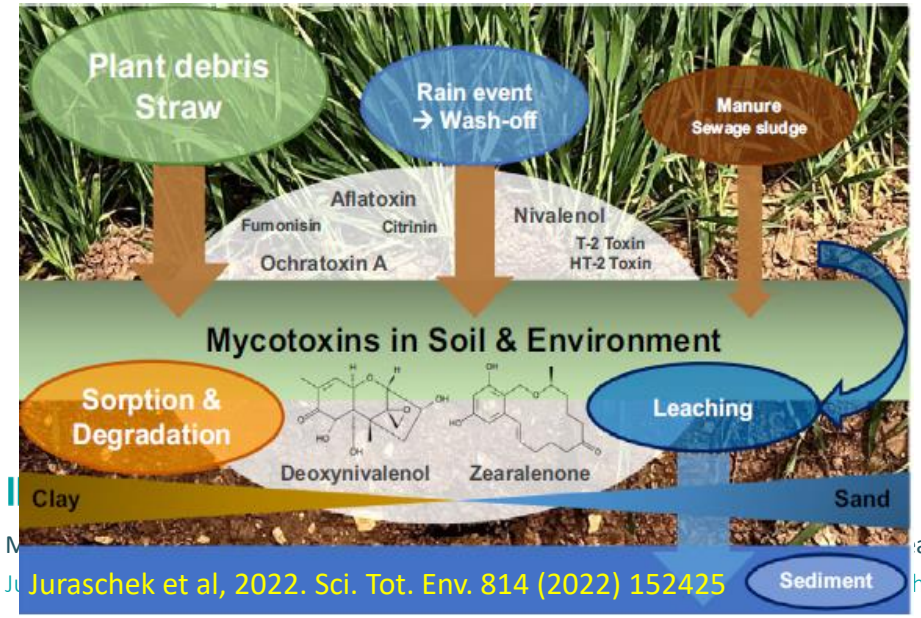
TANGUY & CABEZA-ORCEL Perspectives agricoles 2023 - 512

Mycotoxins issues / From Plant to environment health

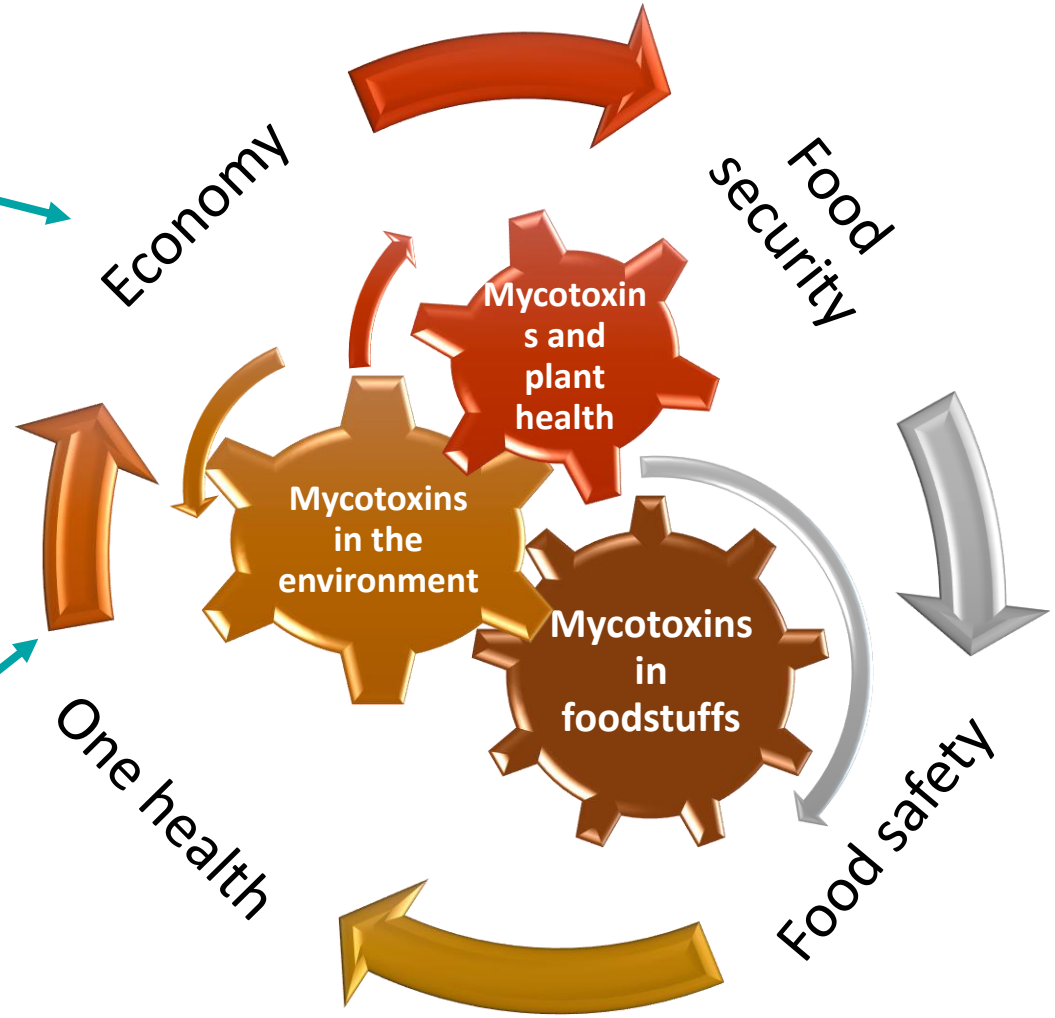
Mycotoxins and plants =

- Phytotoxicity + Mycotoxicity
- Virulence factors in plant diseases
- Also produced by plant rots.
- Present in cultivated plants, in weeds, in plant residues.

Consequences on economy and food security
+ Contamination of soil and environment as side-effect.

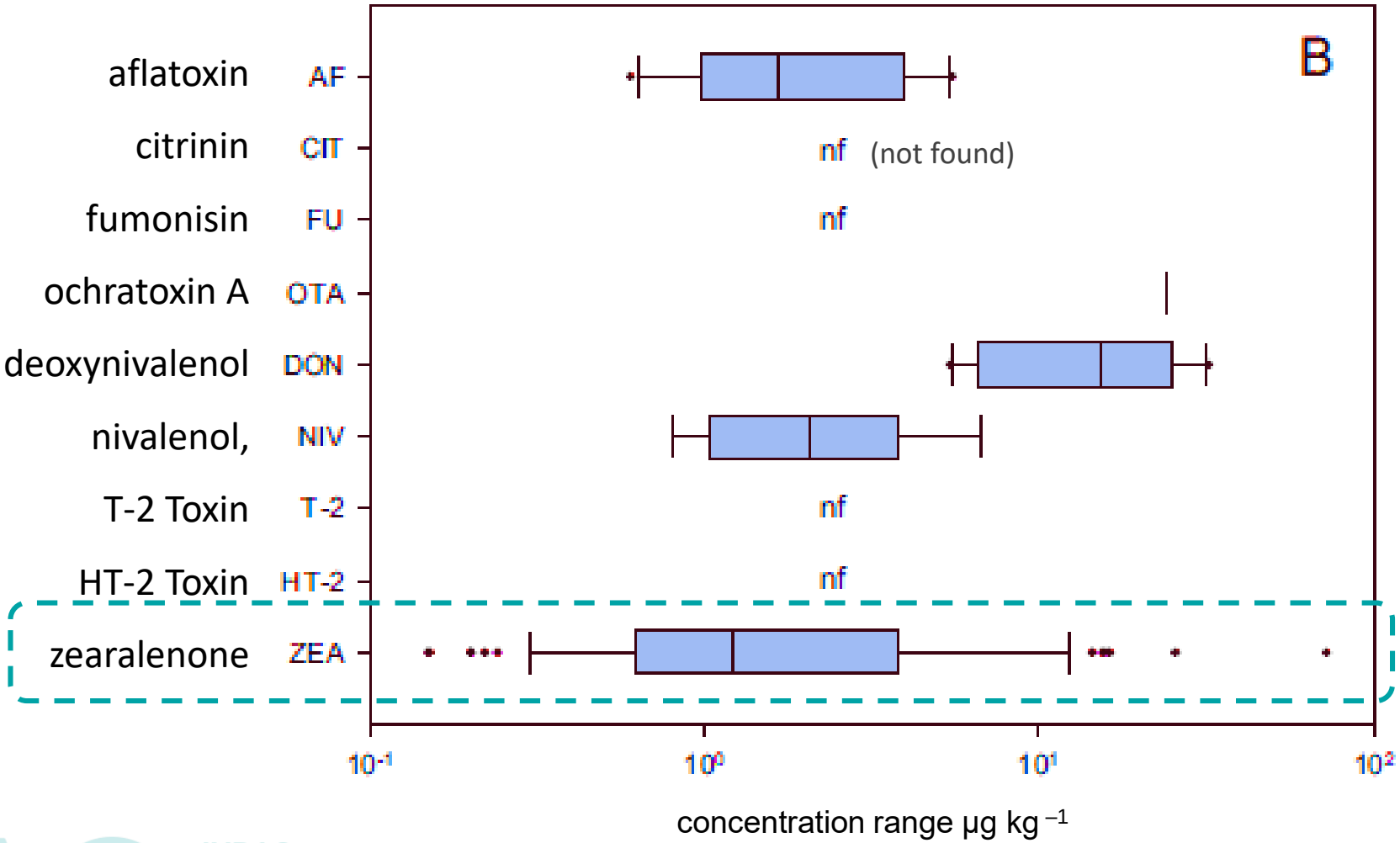


Juraschek et al, 2022. Sci. Tot. Env. 814 (2022) 152425



Mycotoxins issues / Environment health

Mycotoxins in agricultural soils



Other contaminants – typical concentrations in soils :

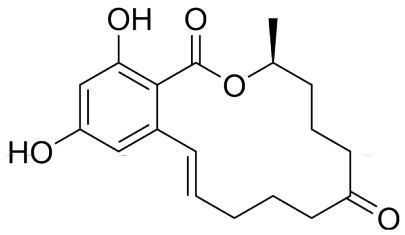
Antibiotics = < 1 µg to several mg kg^{-1} soil

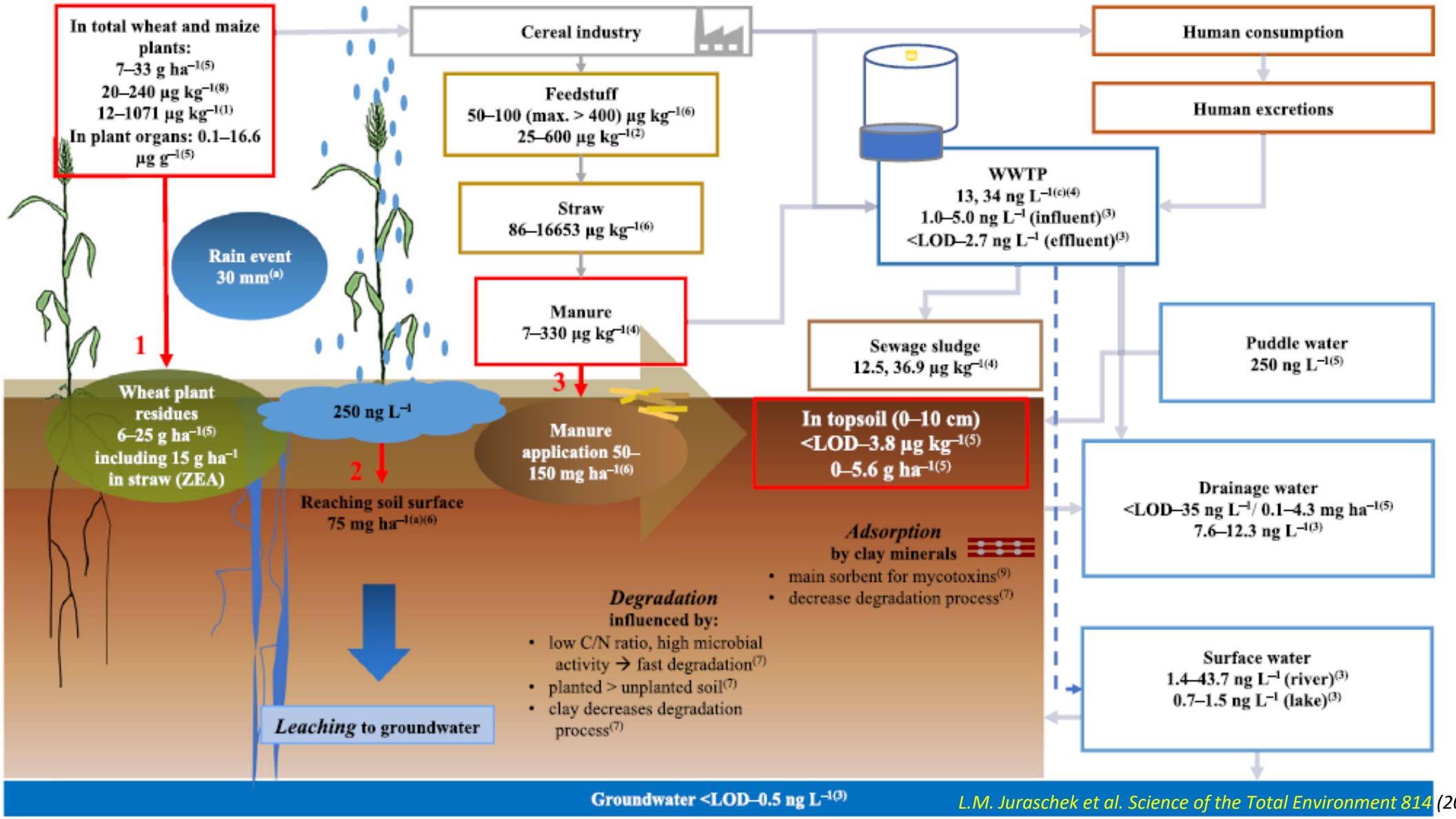
glyphosate = 0.5–5.0 mg kg^{-1}

imidacloprid = 1–100 µg kg^{-1}

L.M. Juraschek et al. Science of the Total Environment 814 (2022) 152425

Possible environmental distribution of the Fusarium mycotoxin zearalenone (ZEA) and main input pathways to soil





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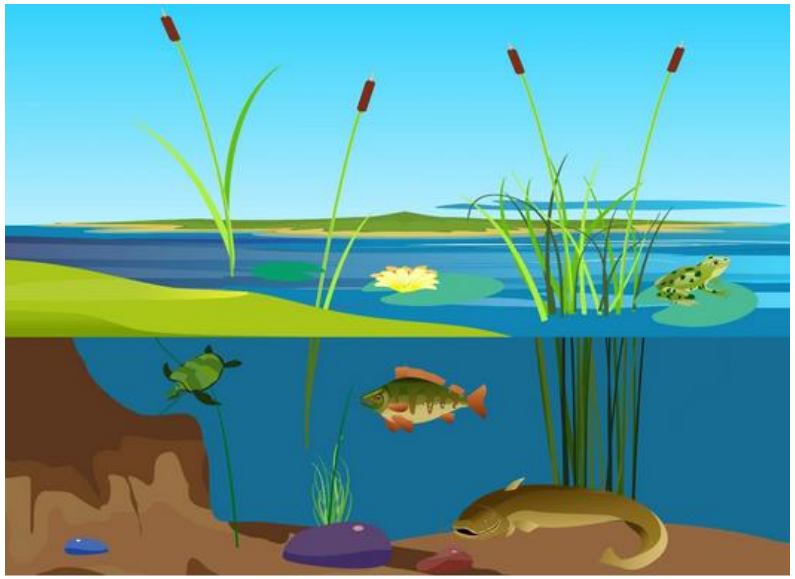
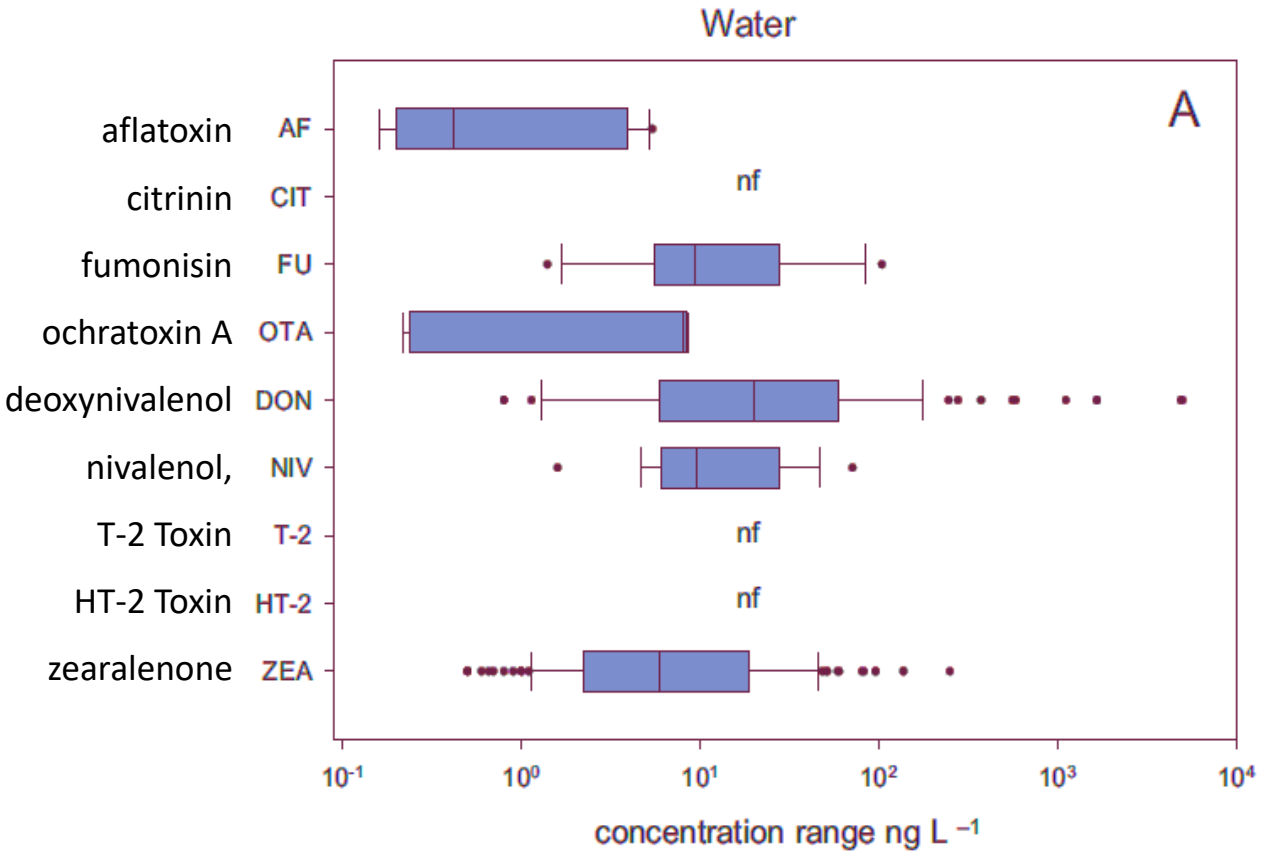
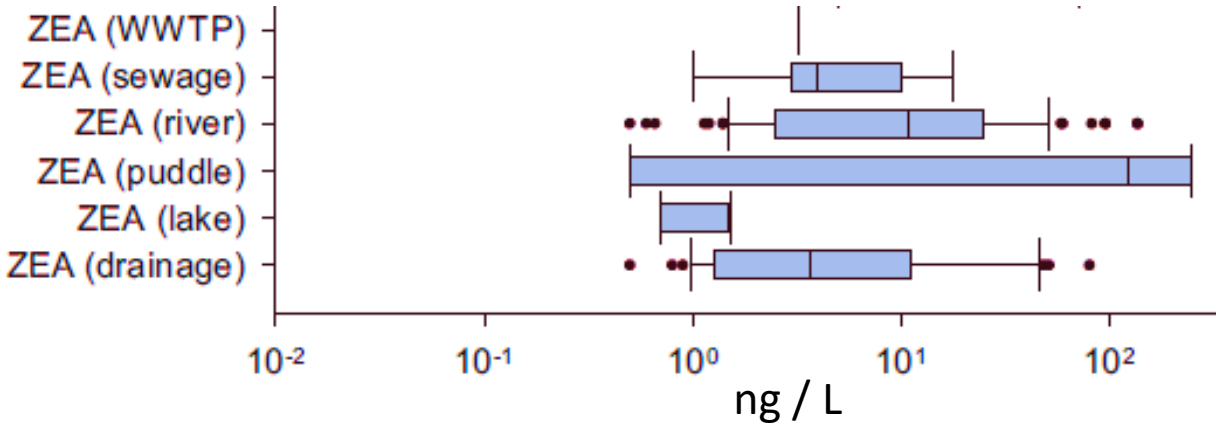
Mycotoxins issues / Environment health

Aquatic environment





WWTP = Waste water treatment plants



L.M. Juraschek et al. Science of the Total Environment 814 (2022) 152425

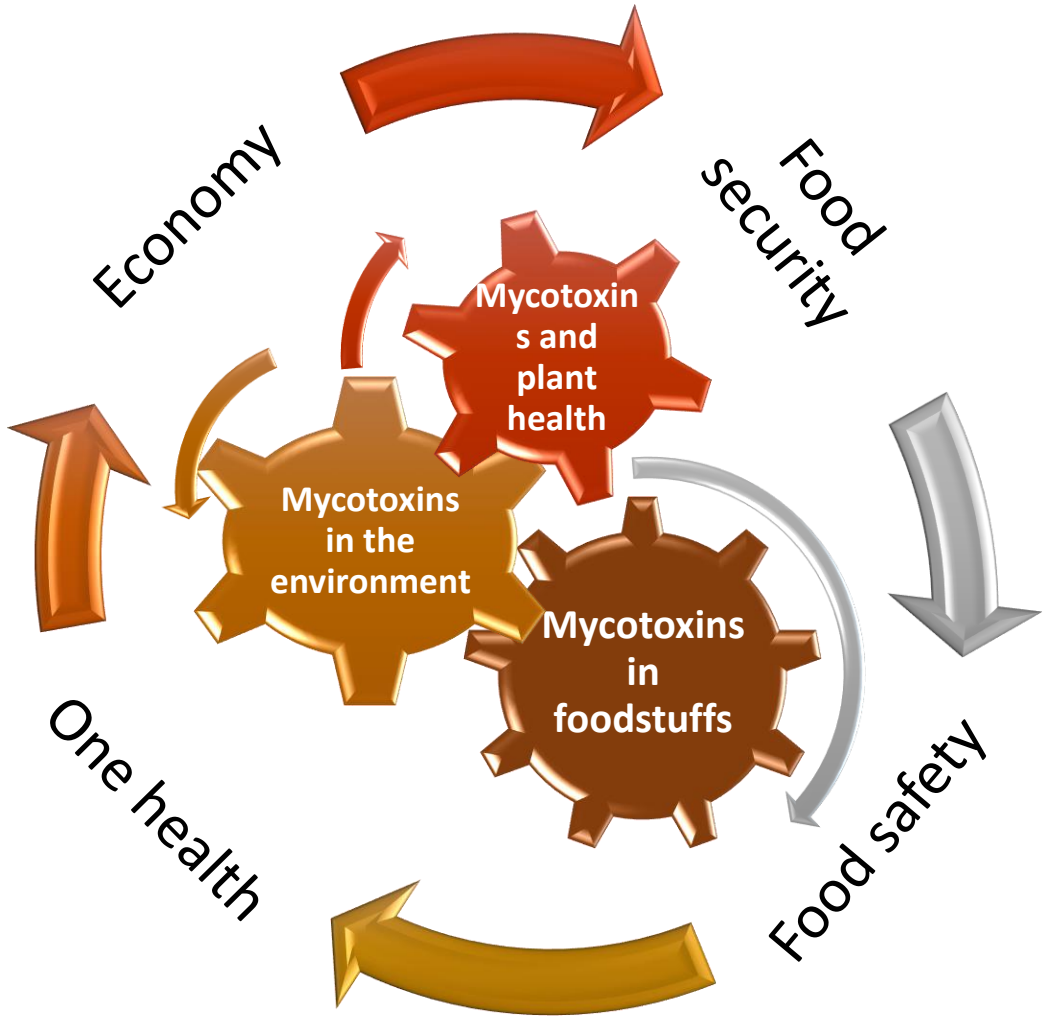
Mycotoxins issues / Environment health

Fate of mycotoxins in the environment ?

Toxicity for micro- and macro-animals in ecosystems ?

Effects on the composition and functionality of environmental microbiota ?

The concentrations are low and the effects should be small but not negligible



Mycotoxins issues / Food safety

COMMISSION REGULATION (EU) 2023/915

of 25 April 2023

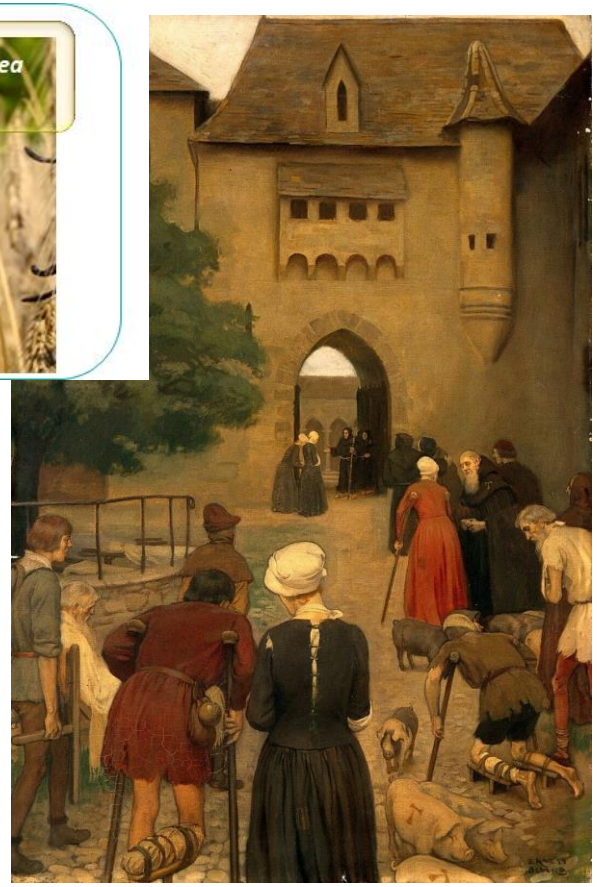
on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006

1.4	**Deoxynivalenol**	Maximum level (µg/kg)	Remarks
1.4.1	Unprocessed cereal grains except products listed in 1.4.2 and 1.4.3	1 250	Except unprocessed maize grains intended to be processed by wet milling and except rice. The maximum level applies to unprocessed cereal grains placed on the market before first-stage processing (6).
1.4.2	Unprocessed durum wheat grains and oat grains	1 750	The maximum level applies to unprocessed cereal grains placed on the market before first-stage processing (6).
1.4.3	Unprocessed maize grains	1 750	Except unprocessed maize grains for which it is evident e.g. through labelling or destination, that they are intended for use in a wet milling process only (starch production). The maximum level applies to unprocessed maize grains placed on the market before first-stage processing (6).
1.4.4	Cereals placed on the market for the final consumer, cereal flour, semolina, bran and germ as final product placed on the market for the final consumer except products listed in 1.4.7 and 1.4.8	750	Except rice and rice products.
1.4.5	Pasta	750	Pasta means pasta (dry) with a water content of approximately 12 %.

European Commission "**mycotoxin contamination results in annual global crop losses of 5 to 10%"** (EC, 2015)
=> € 1.2-2.4 billions of lost income for cereals (*Focker et al 2021)*

Mycotoxins	Related Moulds	Most prone food products to be contaminated	Symptoms / toxicology
Aflatoxins B1, B2, G1, G2	*Aspergillus parasiticus, A. flavus, A. nomius, A. bombycis*	Cereals, groundnut, maize, oil seeds, fruits, nuts, spices, pulses	Hepatotoxic, mutagenic and teratogenic, immunomodulator
Ochratoxin	*A. ochraceus, Penicillium verrucosum, A. carbonarius*	Cereals, coffee, grapes, spices, vegetables	Nephrotoxic, genotoxic, inhibitor of protein, RNA & DNA synthesis
Trichothecenes	*Various Fusarium spp (F. culmorum, F. graminearum, F. poae…), Trichoderma, Cephalosporium, Trichothecium*	Cereals, maize,	Hematoxic, immunomodulator, vomiting, growth retardation
Zearalenone	*Various Fusarium spp (F. graminearum, F. sporotrichoïdes…)*	Cereals, maize,	Oestrogenic effect
Fumonisins	*F. moniliforme, F. verticillioides*	Cereals, maize,	Hepatotoxic genotoxic, immunomodulator, central nervous system injuries
Patulin	*Aspergillus* spp and *Penicillium* spp	Fruits (apples)	Kidney damage, nephrotoxic, immunotoxicity, teratogenic, hepatotoxic, and foetotoxic
Sterigmatocystin	*Aspergillus* spp and *Penicillium* spp	Maize, cereals, hay	Carcinogenic, mutagenic, immunotoxicity, cytotoxicity, diarrhea, nausea, weight loss
Altenaria toxins	*Alternaria* spp.	Cereals, oil seeds, spices, various fruits and vegetables	Cytotoxic, genotoxic, teratogenic, mutagenic, fetotoxic, and dermal toxicity

Human health - Mycotoxins or drug ?



- ✓ Lysergic acid diethylamide (LSD) was discovered as the result of research with ergot alkaloids.
- ✓ Pure ergotamine has been used for the treatment of migraine headaches.
- ✓ Other ergot derivatives are used as prolactin inhibitors, in the treatment of Parkinsonism, and in cases of cerebrovascular insufficiency

- ✓ Enniatins are potential anticarcinogenic drugs.
- ✓ Enniatins have ionophoric, antibiotic and insecticidal activity.

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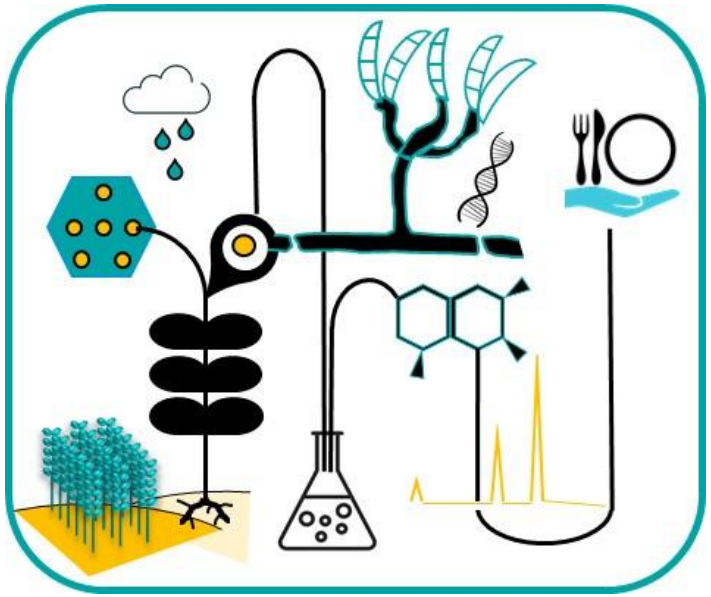
One Health International Days
2024 June 27 & 28

Thank you for your attention



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RMT AL-CHIMIE

MycSA

http://www.rmt-al-chimie.org/moodle/

https://mycsa.bordeaux-aquitaine.hub.inrae.fr/