



Natural products for biocontrol: Fate in the environment and impact on biodiversity

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Natural products for biocontrol: Fate in the environment and impact on biodiversity

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> Introduction

Introduction

Context

- Preservation of biodiversity and ecosystem services is critical for sustainable development and human well-being
 - Unprecedented erosion of biodiversity observed for many years
 - Chemical pollution, including plant protection products (PPPs), is one of the main cause of biodiversity decline (IPBES, 2019)
- French collective scientific assessment (scientific literature survey): Impacts of PPPs on biodiversity and ecosystem services



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Collective scientific assessment
Plant protection products
Biodiversity
Ecosystem services



<https://www.inrae.fr/en/news/impacts-plant-protection-products-biodiversity-and-ecosystem-services-findings-inrae-ifremer-collective-scientific-expert-report>

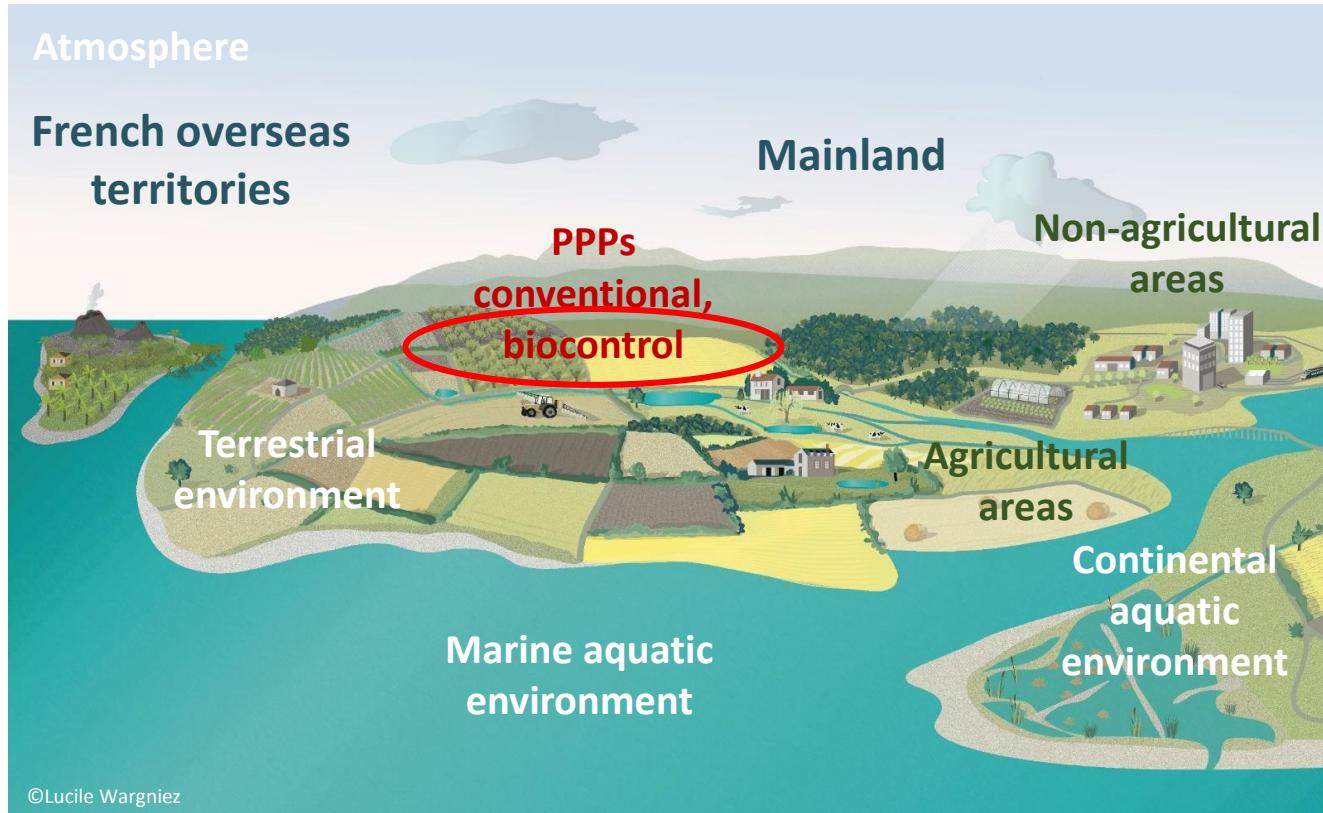
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5th congress Natural products & Biocontrol 2022, Perpignan

Mamy et al. – 23 sept. 2022

Introduction

Collective scientific assessment on the impacts of PPPs on biodiversity and ecosystem services



- Contamination
- Land use and transfers
- Effects on:
 - Primary producers
 - Microorganisms
 - Terrestrial invertebrates
 - Aquatic invertebrates
 - Terrestrial vertebrates
 - Aquatic vertebrates
- Propagation
- Ecosystem services
- Biocontrol
- Modelling
- Regulation

- **Biocontrol:** Set of crop protection methods defined as agents and products using natural mechanisms in the context of integrated pest management

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➤ Introduction

Objective and approach

Objective

- To determine the sustainability of biocontrol solutions

Approach

- To review:
 - The contamination of the environment by biocontrol solutions
 - The fate of biocontrol solutions in the environment
 - The effects of biocontrol solutions on the biodiversity
 - The effects of biocontrol solutions compared to those of conventional PPPs



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► Biocontrol solutions

► Biocontrol solutions

Macroorganisms (examples)

Predators



Adalia bipunctata



Aphidoletes aphidimyza



Chrysoperla rufilabris



Forficula auricularia



Macrolophus pygmaeus



Cryptolaemus montrouzieri

Parasitoids



Diachasmimorpha tryoni



Lysiphlebus testaceipes



Trichogramma brassicae



Opis arisanus



Trichopoda pilipes



Trissolcus basalis

Nematodes



Heterorhabditis indica



Steinernema carpocapsae

► Biocontrol solutions

Microorganisms (examples)

Bacteria

- *Bacillus amyloliquefaciens*
- *Bacillus firmus*
- *Bacillus pumilus*
- *Bacillus thuringiensis* (Bt)
- *Bacillus subtilis*
- *Pseudomonas*



Bacillus thuringiensis

Fungi

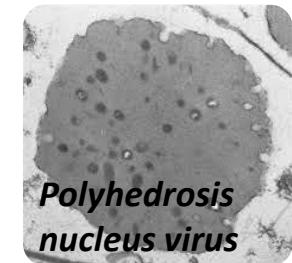
- *Beauveria bassiana*
- *Clonostachys rosea*
- *Metarhizium anisopliae*
- *Pythium oligandrum*
- *Saccharomyces cerevisiae*
- *Trichoderma atroviride*



Trichoderma atroviride

Virus

- *Cydia pomonella granulosis virus*
- *Pepino mosaic virus*
- *Polyhedrosis nucleus virus*



*Polyhedrosis
nucleus virus*

➤ Biocontrol solutions

Natural substances (examples)

Plants

- 6-benzyladenine
- Caprylic acid
- Eugenol
- Fatty acids
- Garlic extract
- Geraniol
- Gibberelins
- Heptamaloxylglucan
- Maltodextrin
- Orange oil
- Pelargonic acid
- Pyrethrins
- Rape oil
- Terpenoids mixture
- Thymol



Minerals

- Disodium phosphonate
- Ferric phosphate
- Iron sulfate
- Kaolin
- Paraffin oil
- Potassium hydrogenocarbonate
- Potassium phosphonate
- Quartz sand
- Sulfur



Animals

- Blood meal
- COS-OGA
- Fish oil
- Sheep fat



Microbial

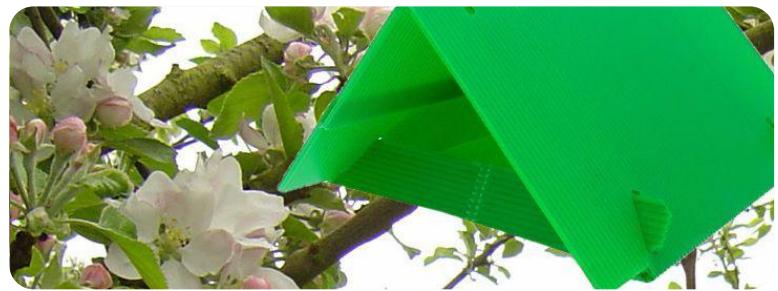
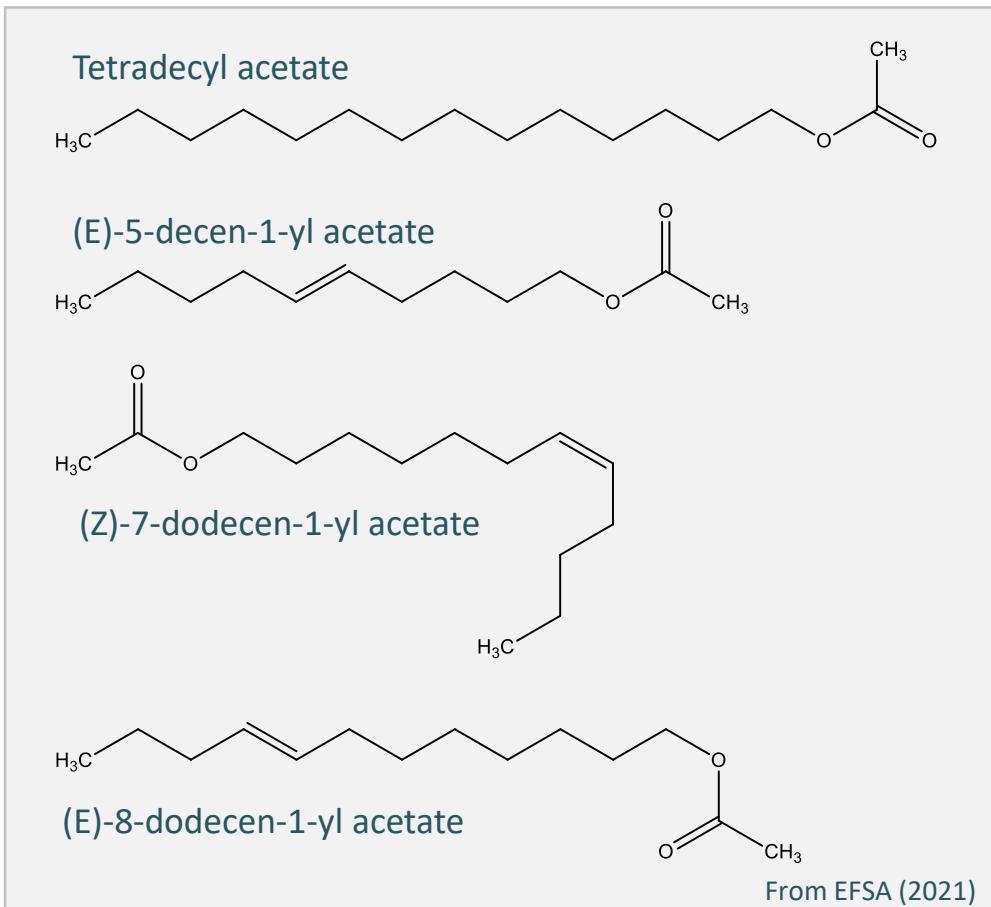
- Abamectin
- Acetic acid
- Cerevisane
- Diatomaceous earth
- Spinosad



► Biocontrol solutions

Semiochemicals (examples)

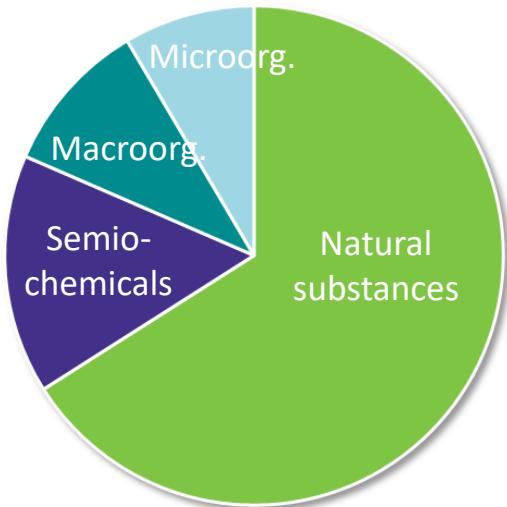
- Straight chain lepidopteran pheromones



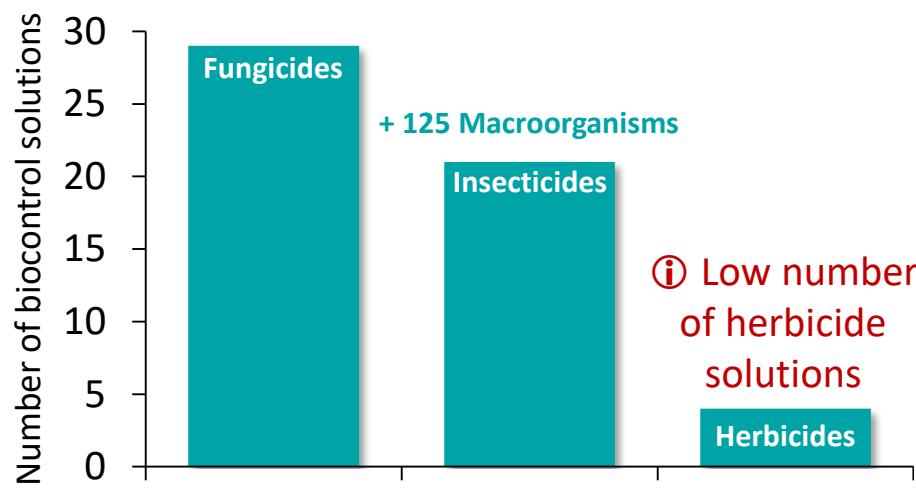
➤ Biocontrol solutions

Example of the France case study

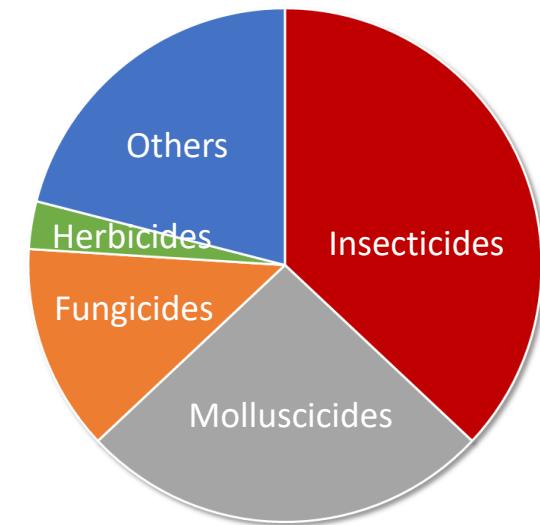
- Biocontrol market booming : 12% of PPPs market in 2020, 30% expected in 2030 (IBMA, 2021)



Use of biocontrol solutions
(% market share 2020) (IBMA, 2021)
NB : Sulfur is the most used solution



Number of active substances, micro and macroorganisms species per fungicide, insecticide or herbicide use (DGAL, 2021)



Sales of biocontrol solutions
(% market share 2020) (IBMA, 2021)



➤ Bibliographic corpus

> Bibliographic corpus

Definition of queries and keywords

Query 1

General

Unspecific keywords /
Biocontrol

Biological control
Biocontrol
Semiachemical
Natural extract
Plant extract
Natural substance
Biopesticide, etc.

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Query 2

*Microorganisms, Natural substances,
Semiachemicals*

French list of biocontrol
plant protection products
of the Rural Code and
Maritime Fishing



Bacillus thuringiensis
Beauveria bassiana
Trichoderma asperellum
Straight chain lepidopteran pheromone
Abamectin
Acetic acid
Eugenol
Heptamaloxylglucan, etc.

Query 3

Macroorganisms



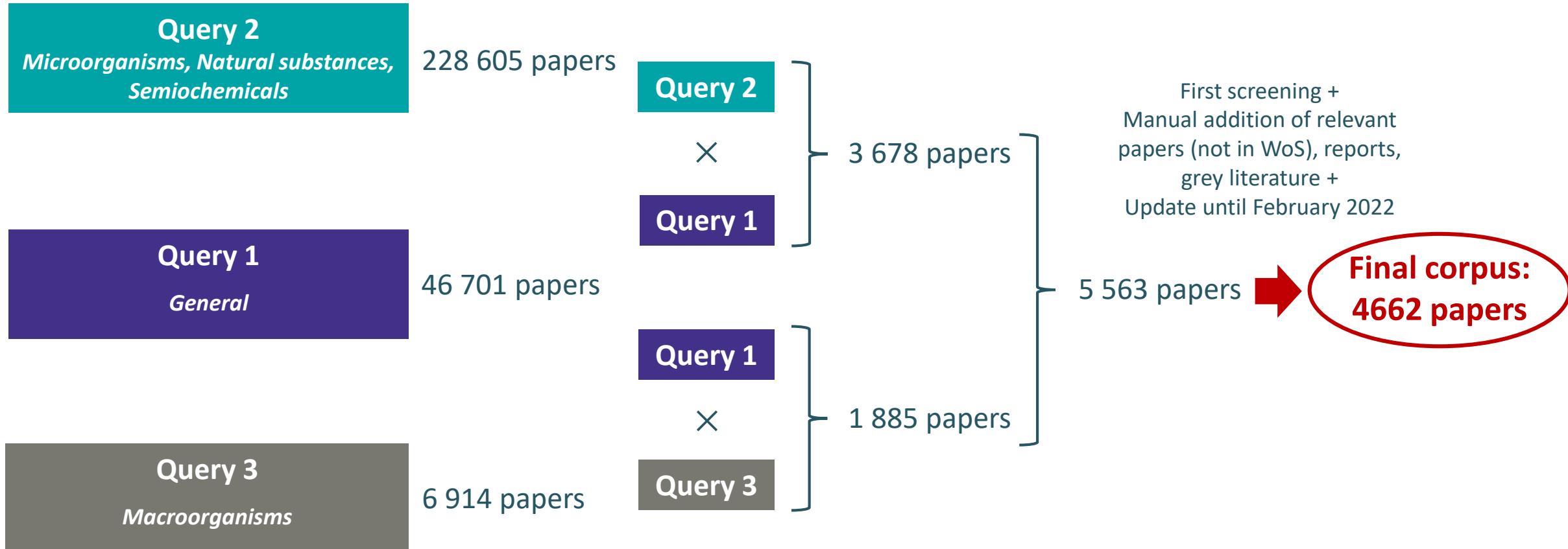
Innovations Agronomiques 79 (2020), 425-439

Macroorganismes de biocontrôle en France, état des lieux
Biocontrol macroorganisms in France, state of the art
Robin D.C.¹, Marchand P.A.¹

Adalia bipunctata
Bombus terrestris
Chrysoperla carnea
Harmonia axyridis
Leptomastidea abnormis
Orius laevigatus
Osmia bicornis
Trichogramma achaeae, etc.

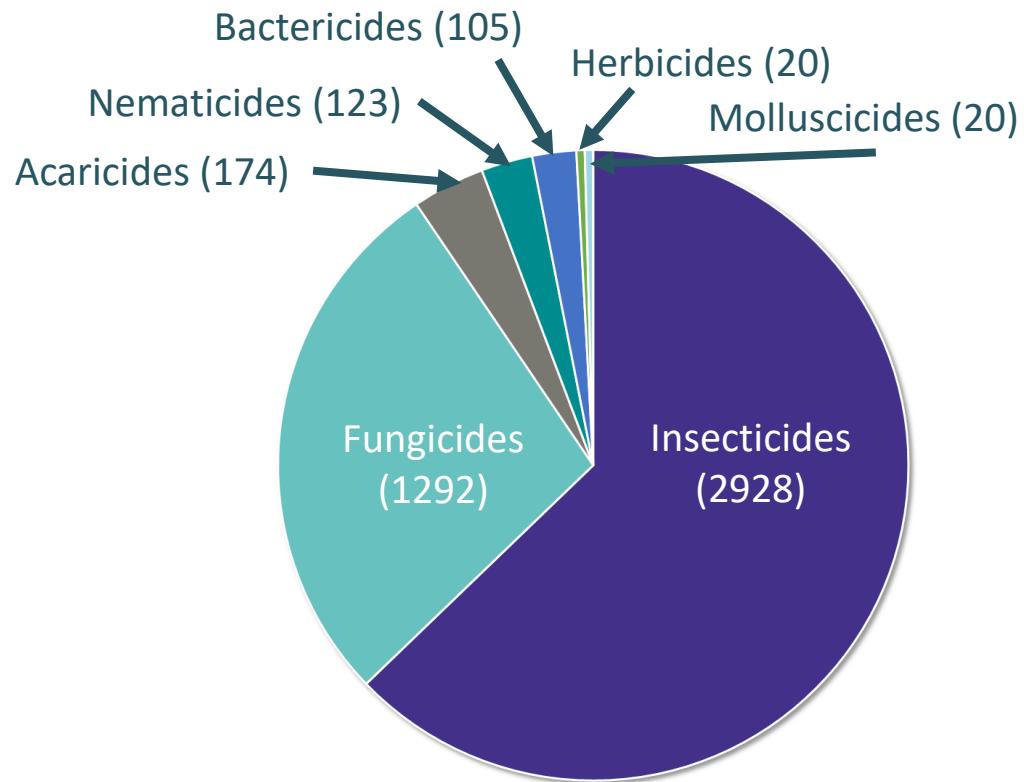
➤ Bibliographic corpus

Selection of papers in the Web of Science™ (WoS) from 2000 to 2020



> Bibliographic corpus

Distribution of papers according to the usage of biocontrol products



- Huge number of papers / insecticides, fungicides
- Very low number of papers / herbicides, molluscicides
- Consistency between the number of papers and the sale volumes (France case study), except for molluscicides



➤ Contamination of the environment by biocontrol
solutions

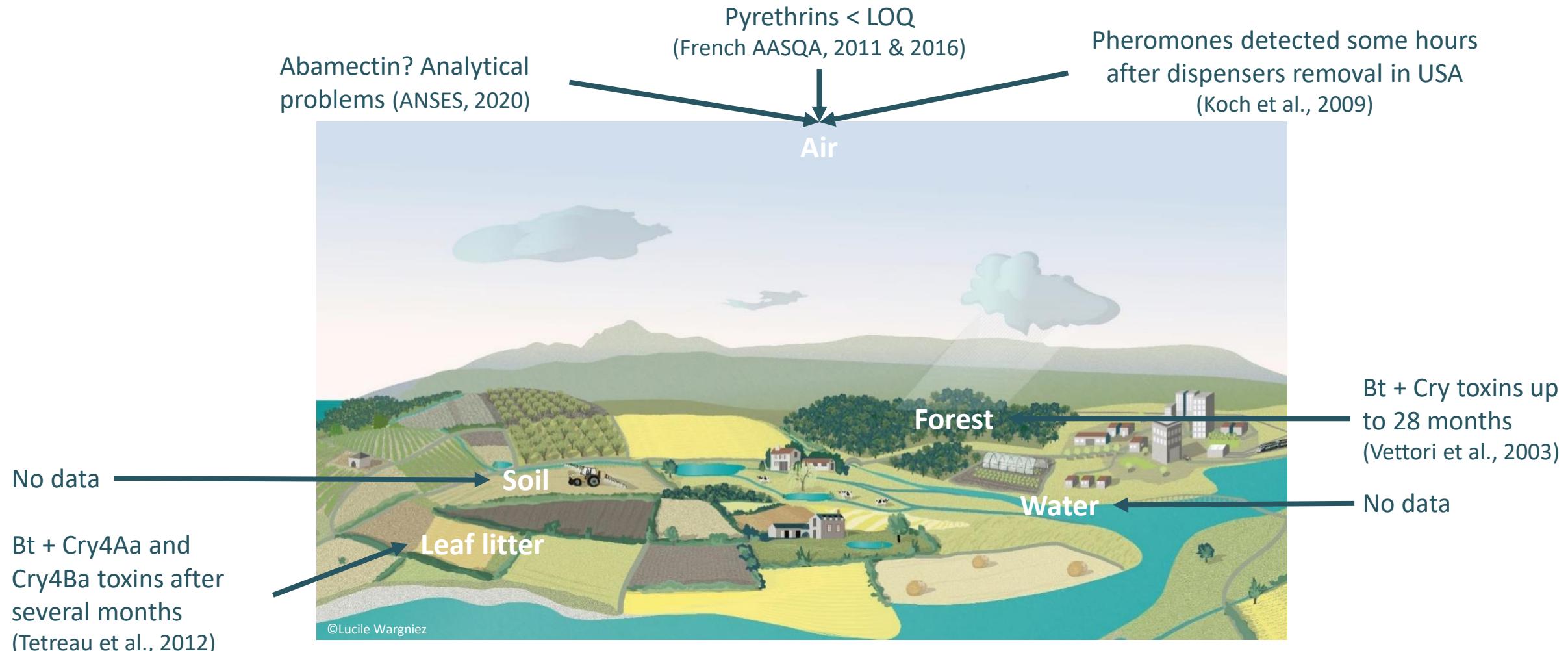
➤ Contamination of the environment

- Biocontrol compounds are very rarely searched in the environment
 - Some of them are naturally present: fatty acids, potassium hydrogen carbonate, aluminum silicate, sulfur...
 - Fraction coming from products / native fraction?
 - Some compounds have a chemical nature that is not compatible with analytical monitoring: blood meal, fish oil, sheep fat...
- **Very few results for exogenous biocontrol substances that can be measured in the environment**



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> Contamination of the environment

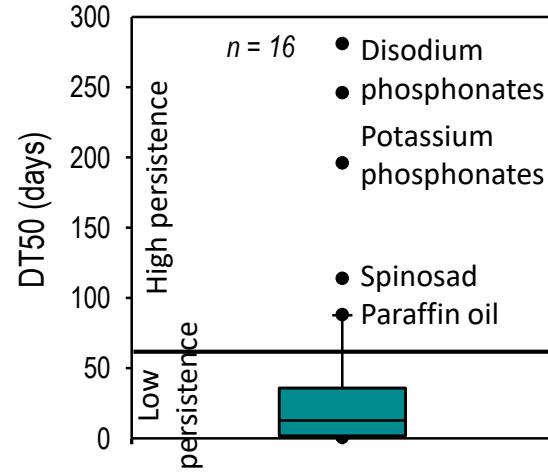




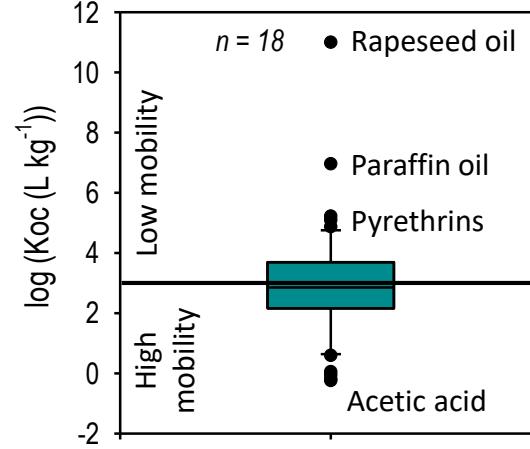
➤ Fate of biocontrol solutions in the environment

Fate in the environment

Natural substances



Boxplots of the distribution of DT50 and Koc of natural substances
(From Mamy and Barriuso, 2022)



- Many natural substances have a low persistence in the environment
- ⓘ The degradation may produce transformation products (abamectin, spinosad)

- Some substances are immobile contrary to others having high mobility
- Risk of groundwater contamination

➤ Lack of persistence and mobility data for several substances

➤ Fate in the environment

Microorganisms, macroorganisms and semiochemicals



Microorganisms

- Fungal-based insecticides are persistent in the environment (Meyling and Eilenberg, 2007)
- Persistence of Bt insecticide several months and years (Tetreau et al., 2012; Bruhl et al., 2020; Liu et al., 2021)
- Fungal-based and bacteria-based fungicides are not persistent (Kohl et al., 2019)



Macroorganisms

- Persistence in the short term well known (efficacy)
- Persistence in the long term?



Semiochemicals

- No data

➤ Lack of data to characterize the fate of microorganisms, macroorganisms and semiochemicals in the environment

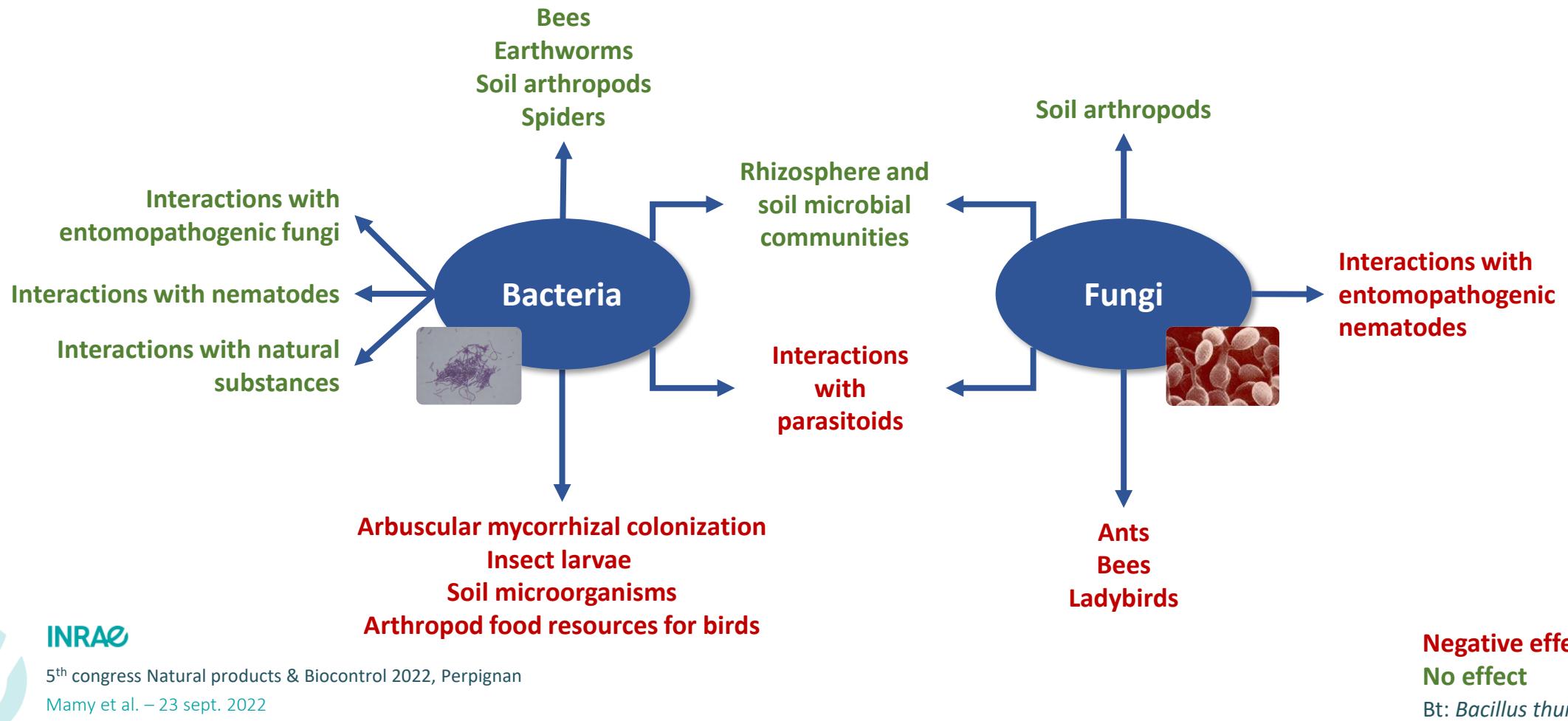


➤ Ecotoxicological effects of biocontrol solutions
and impact on biodiversity

Microorganisms

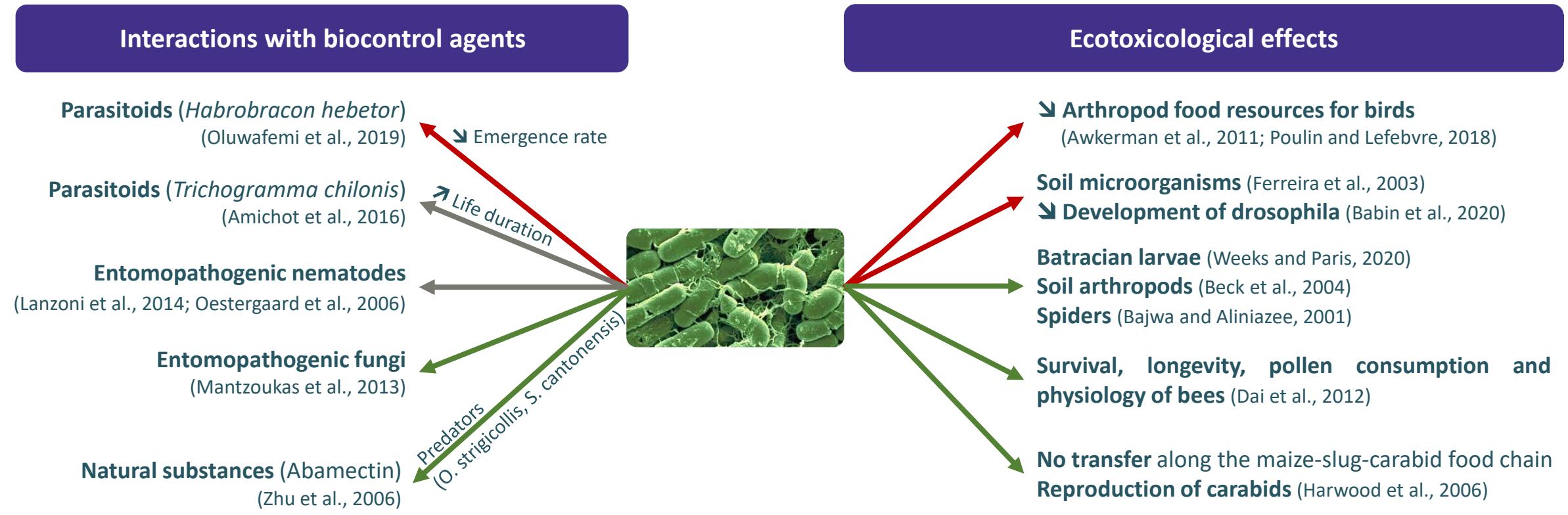
Summary of observed effects

- Most of results for Bt bacteria, some results for *Beauveria Bassiana* and *Metarhizium anisopliae* fungi, no result for virus



Microorganisms

Example of *Bacillus thuringiensis* (Bt)



➤ High complexity of interactions between Bt and biocontrol agents and between Bt and other (micro)organisms

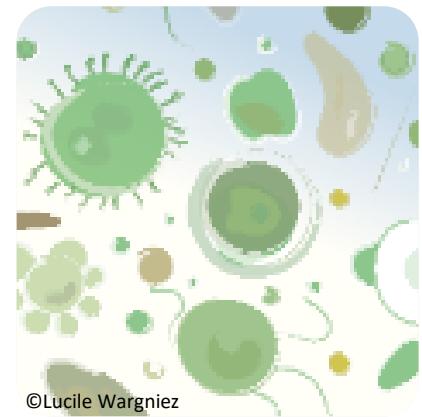
➤ Microorganisms

Main conclusions

- Limited impact of microorganisms on soil micro-biodiversity, except for Bt
- Some effects of fungi on various organisms

➤ Need of more data:

- Impacts of microorganisms on biodiversity
- Impacts of virus
- Invasion of microorganisms
- “Cocktail” effects on local biodiversity
- Effects on ecological functions and ecosystem services

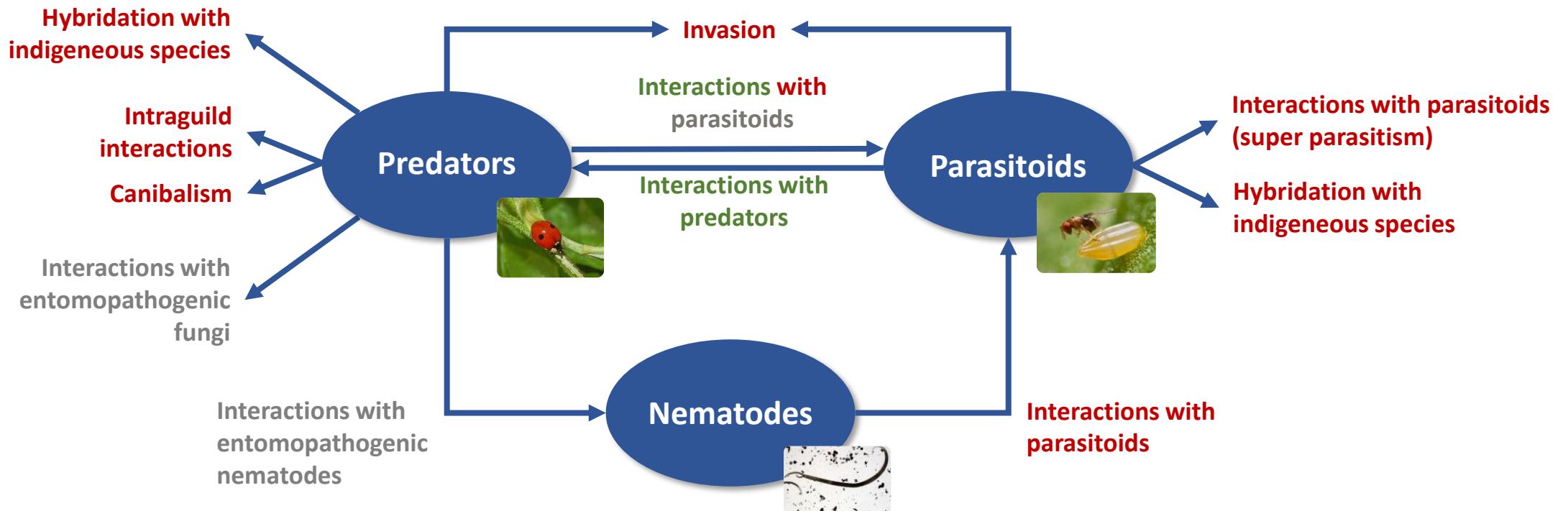


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Macroorganisms

Summary of observed effects

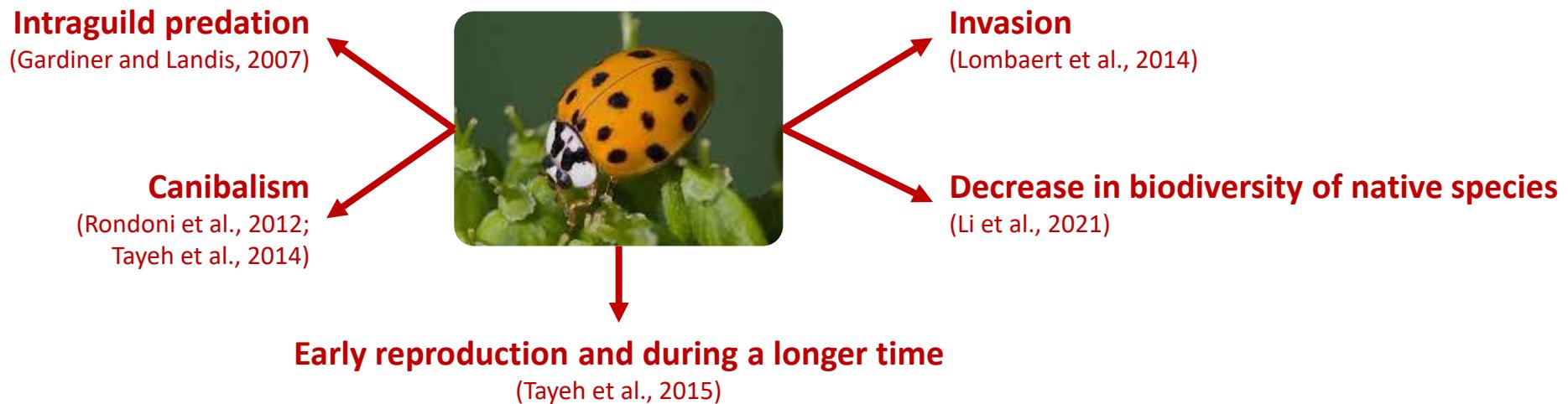
- Affect the biodiversity through their mode of feeding, their ability to move and their ability to reproduce



Macroorganisms

Example of *Harmonia axyridis* predator escape

- Introduction to impose top-down population regulation of pests, in particular aphids



➤ Illustration of what should not be done in biocontrol

➤ Macroorganisms

Main conclusions

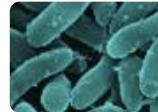
- High complexity of modes of action
- Interactions among them or with local organisms
- Direct interactions: predation, parasitism, hybridization
- Indirect interactions: competition for resources
- Change in host or preys

- “Cocktail” effects on local biodiversity?
- Effects on ecological functions and ecosystem services?



> Natural substances

Summary of observed effects



- Most of results for abamectin, spinosad and pyrethrins

ⓘ Similar modes
of action as
conventional
PPPs

- Observed ecotoxicity of natural substances, especially abamectin and spinosad

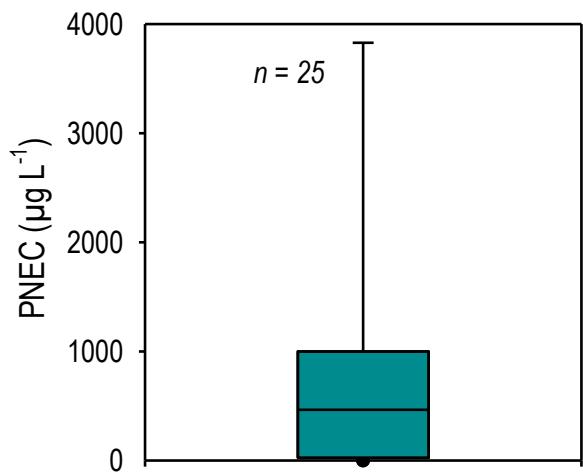
▶ Natural substances

Main conclusions

- In general, natural substances have a low ecotoxicity
- But, some of them have high ecotoxicity (abamectin, spinosad...)
- Lack of data for numerous substances

➤ Need of more data:

- Impacts of natural substances on biodiversity
- Chronic effects at low doses
- “Cocktail” effects on local biodiversity
- Effects on ecological functions and ecosystem services



Boxplots of the distribution of PNEC
of natural substances
(From Mamy and Barriuso, 2022)



> Semiochemicals

➤ No data!



➤ Comparison of the effects of biocontrol solutions
with those of conventional PPPs

➤ Effects of biocontrol solutions / conventional PPPs

- BIOCONTROL SOLUTIONS SEEM TO HAVE LOWER ECOTOXICITY THAN CONVENTIONAL PPPS, BUT THERE ARE SOME EXCEPTIONS

➤ Need of more data

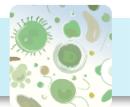


> Conclusion

> Conclusion (1/2)

> Very few results in the literature

Microorganisms



- High persistence of some insecticides (Bt), low persistence of fungicides
- Some observed effects
- Change in soil biodiversity?
- Invasion of non native species?

Macroorganisms



- Direct effects: predation, hybridation
- Indirect effects: competition / resources
- Decrease in local biodiversity (*H. axyridis*)
- Persistence in the long term?

Natural substances



- Low persistence in the environment
- Low ecotoxicity / conventional PPPs
- ⓘ Abamectin, spinosad, pyrethrins
- Contamination?

Semiochemicals



- ?



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➤ Conclusion (2/2)

- Contamination?
- Chronic effects?
- “Cocktail” effects?
- Effects on ecological functions and ecosystem services?
- Nanoparticules?
- Risk assessment and regulation?
- Management of potential invasion?
- Biocontrol / conventional PPPs?



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- **Biocontrol is a promising alternative to conventional PPPs, but it depends on the type of solution (and lack of herbicide solutions)**
- **Numerous research still remains to be done**

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