

Outsmarting wireworms

Combining semiochemicals and entomopathogens for sustainable management



Prof François Verheggen

Gembloux Agro-Bio Tech - Université de Liège



Wireworms

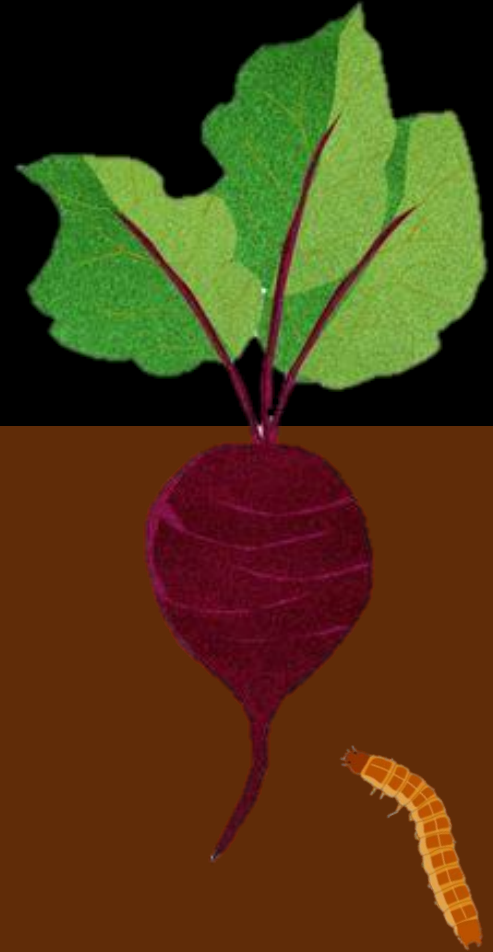
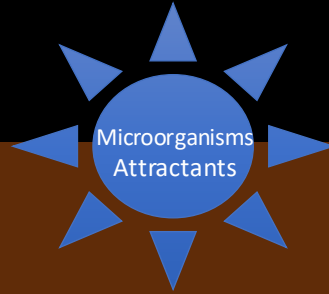
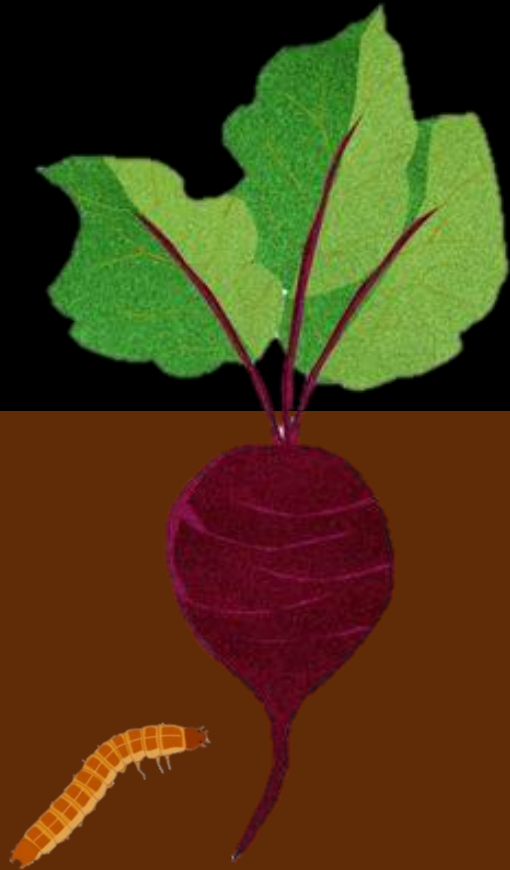
(Agriotes sp., Coleoptera, Elateridae)





Development of an Attract-&-Kill formulation

- * Attractive
- * Efficient
- * Specific
- * Biodegradable
- * Easy to handle



Development of an Attract-&Kill formulation

Attractant



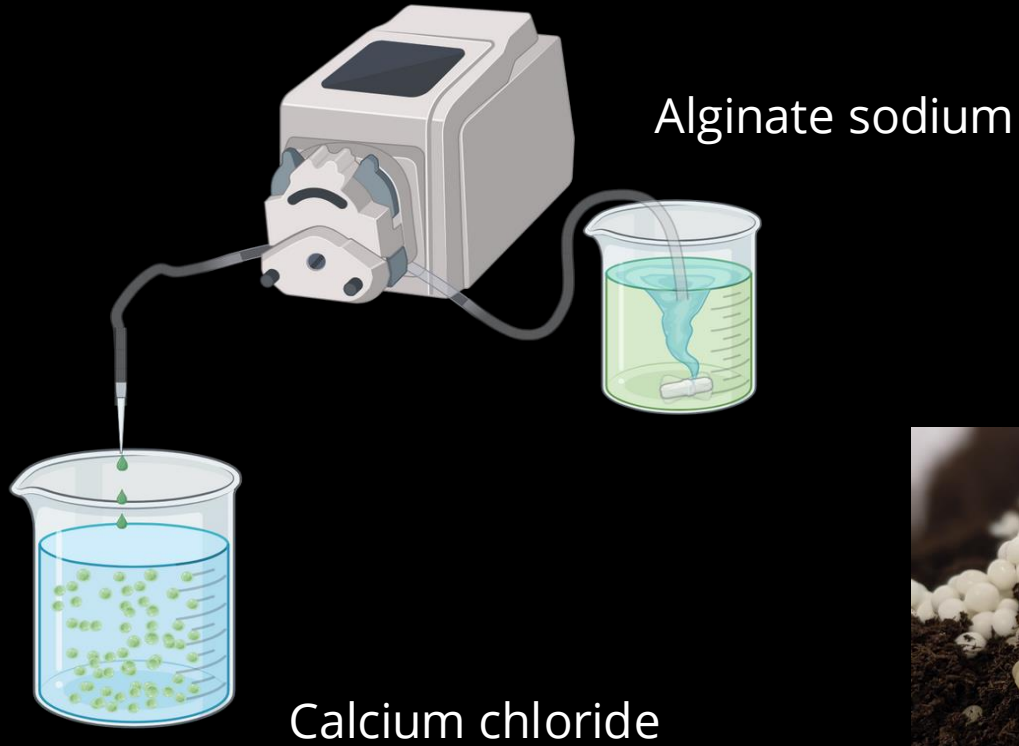
Nematodes



Fungi



Development of an Attract-&Kill formulation



Optimising the attractant

- Kairomones
- Plant extracts
- Pheromones

Optimising the microbial killer

- Entomopathogenic nematodes
- Entomopathogenic fungi

Side effects on non target species

- Ground beetles
- Ants
- Earthworms

Testing the formulation outside the laboratory

- Sugar beet fields

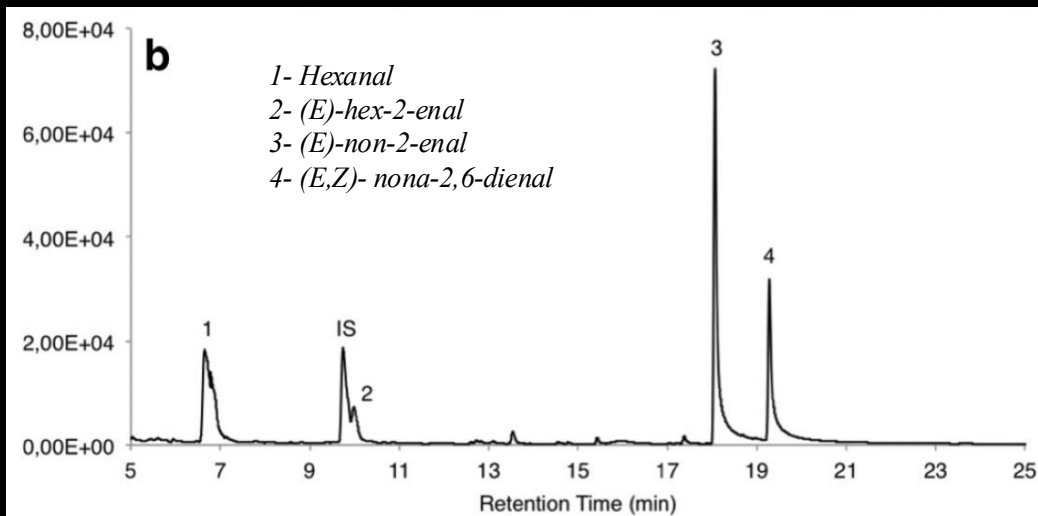




Characterization of Volatile Organic Compounds Emitted by Barley (*Hordeum vulgare* L.) Roots and Their Attractiveness to Wireworms

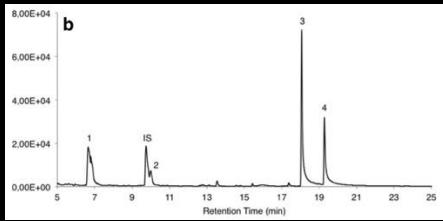
Aurélien Gfeller · Morgan Laloux · Fanny Barsics · Djamel Edine Kati ·
Eric Hanbrug · Patrick du Jardin · François J. Verheggen ·
Georges Lognay · Jean-Paul Wathelet · Marie-Laure Fauconnier

Barley roots volatiles



Foraging wireworms are attracted to root-produced volatile aldehydes

Fanny Barsics¹ · Benjamin M. Delory^{2,4} · Pierre Delaplace² · Frédéric Francis¹ · Marie-Laure Fauconnier² · Éric Haubruge¹ · François J. Verheggen¹

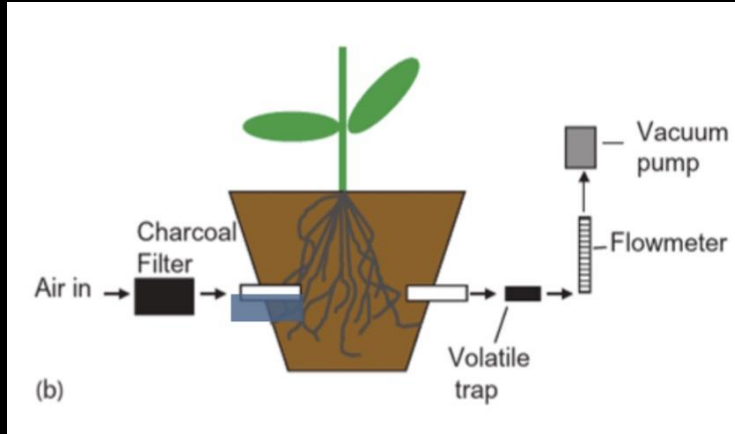


66%

0,032*

→ Wireworms are attracted by the aldehydes produced by barley roots

Additional plant volatile collection to identify more attractants ...



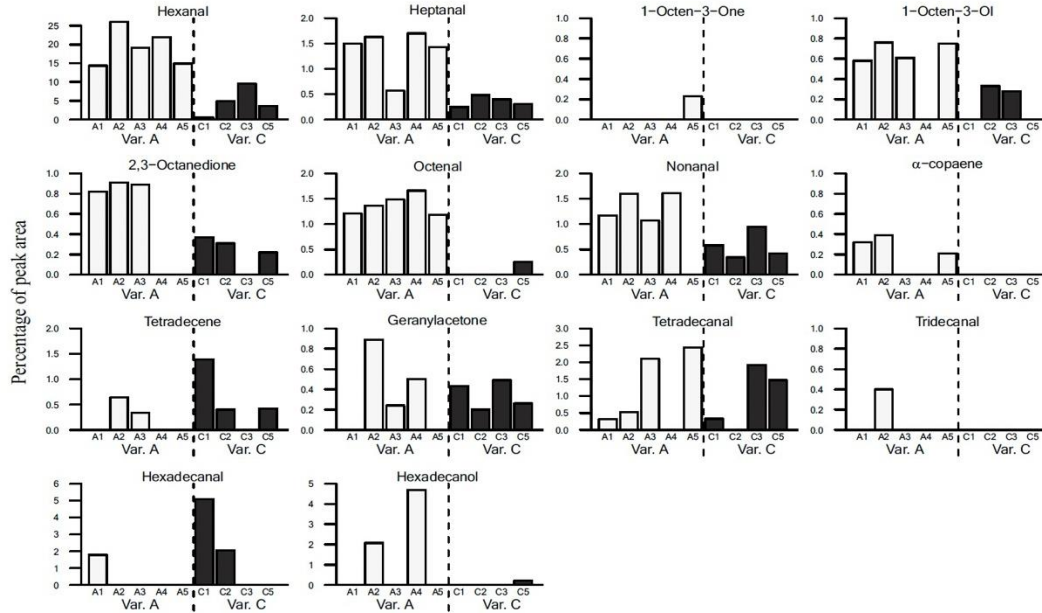
Additional plant volatile collection to identify more attractants ...

Linking variety-dependent root volatile organic compounds in maize with differential infestation by wireworms

Diana la Forgia¹ · Jean-Baptiste Thibord² · Philippe Larroudé² · Frédéric Francis¹ · Georges Lognay¹ · François Verheggen¹ 



Diana La Forgia

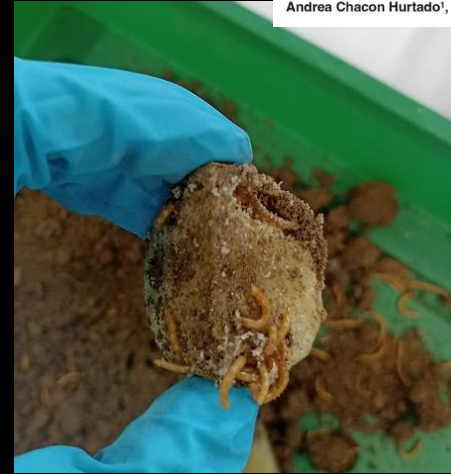


Potato cultivar susceptibility to wireworms: feeding behaviour, fitness and semiochemical-based host selection

Andrea Chacon Hurtado¹, Fanny Ruhland¹, Antoine Boullis¹, François J. Verheggen^{1,*}



Andrea Chacon



Field susceptibility

Charlotte



Spunta



Monalisa

→ Hypothesis: different levels of attack are linked to different levels of attractiveness and volatile attractants

Potato cultivar susceptibility to wireworms: feeding behaviour, fitness and semiochemical-based host selection

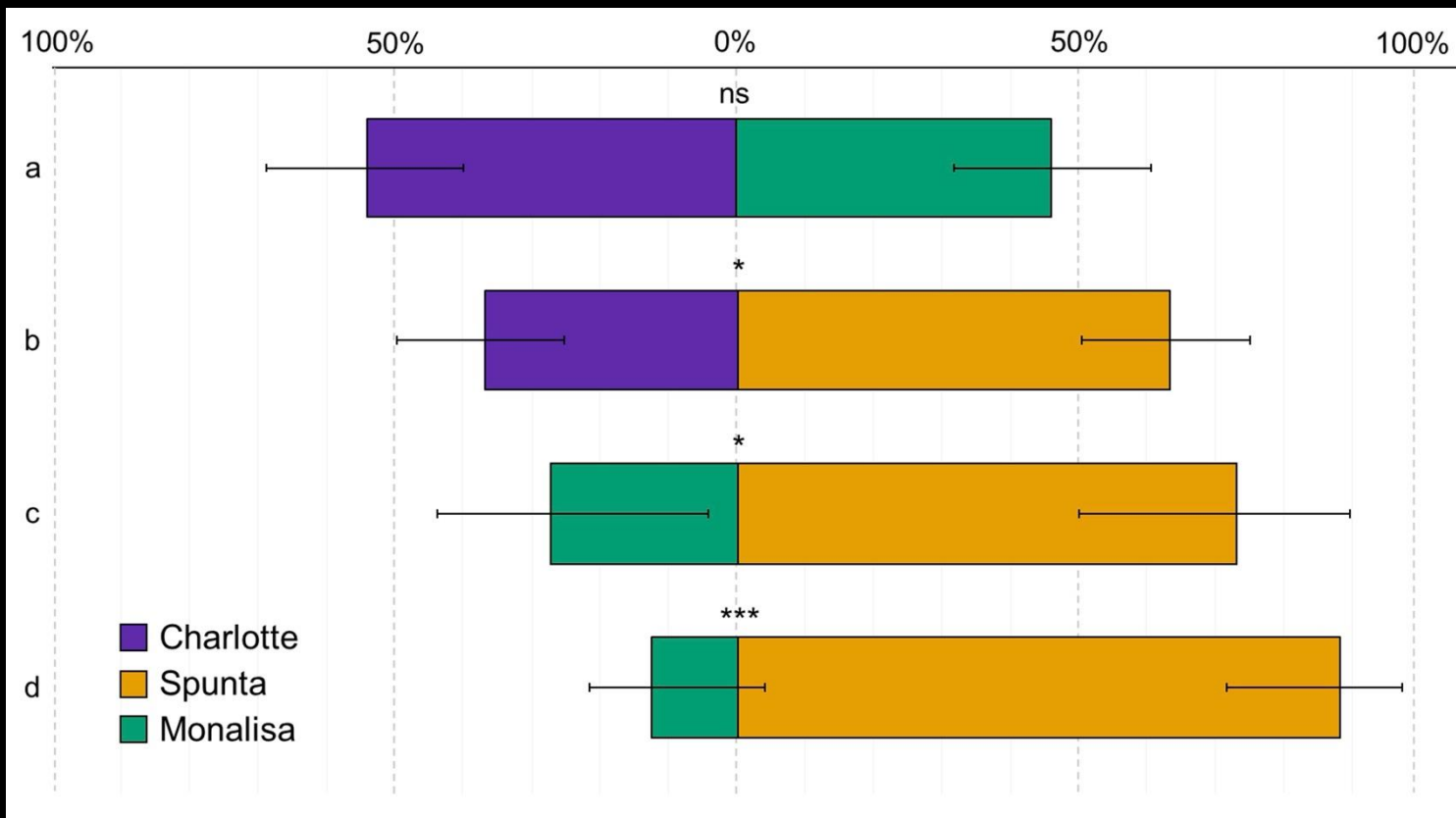
Andrea Chacon Hurtado¹, Fanny Ruhland¹, Antoine Boullis¹, François J. Verheggen^{1,*}



Dual choice bioassays

Potato cultivar susceptibility to wireworms: feeding behaviour, fitness and semiochemical-based host selection

Andrea Chacon Hurtado¹, Fanny Ruhland¹, Antoine Boullis¹, François J. Verheggen^{1,*}



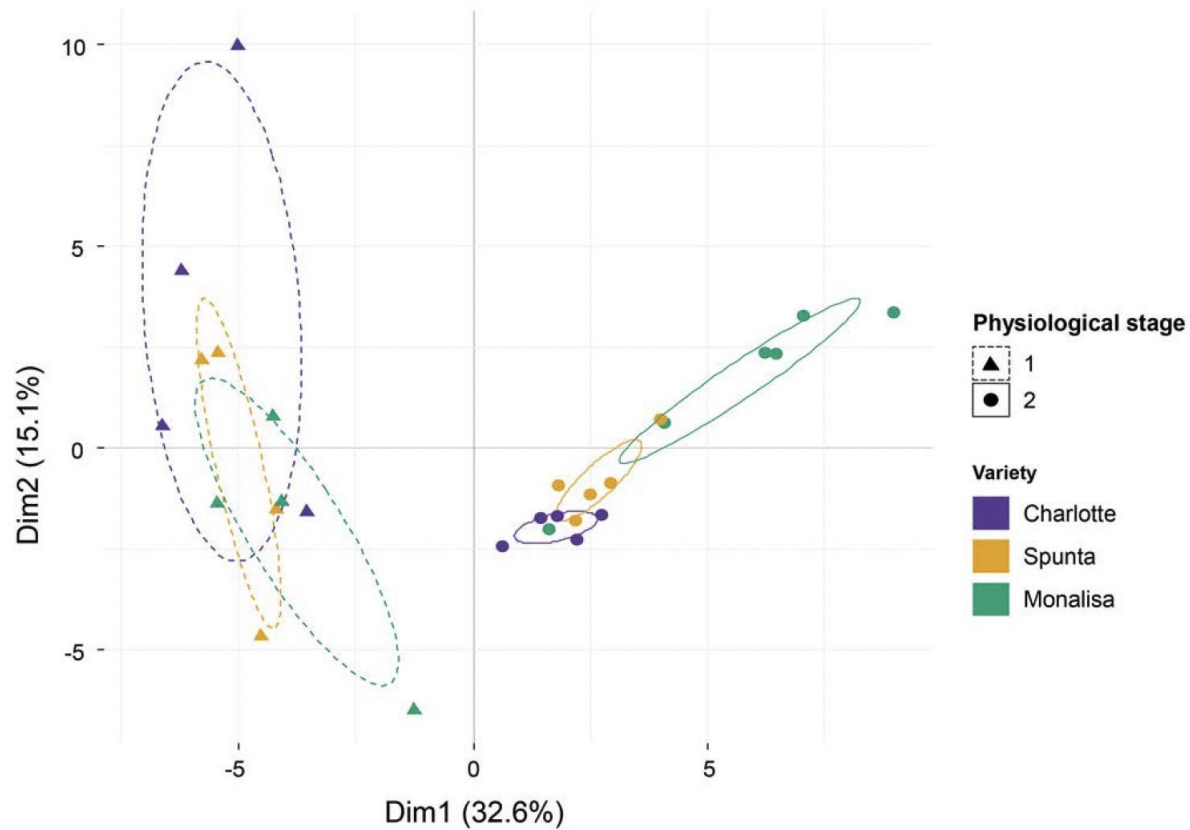
Potato cultivar susceptibility to wireworms: feeding behaviour, fitness and semiochemical-based host selection

Andrea Chacon Hurtado¹, Fanny Ruhland¹, Antoine Boullis¹, François J. Verheggen^{1,*}



Potato cultivar susceptibility to wireworms: feeding behaviour, fitness and semiochemical-based host selection

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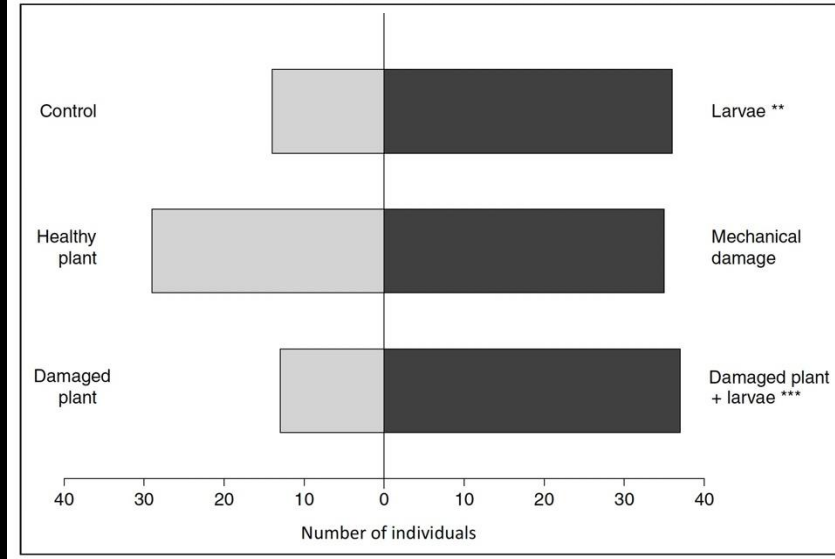


2-Pentylfuran: an aggregation attractant for wireworms

Diana la Forgia^{1,3} · Clément Martin¹ · Ted C. J. Turlings² · François Verheggen¹



Diana La Forgia



Plant extracts

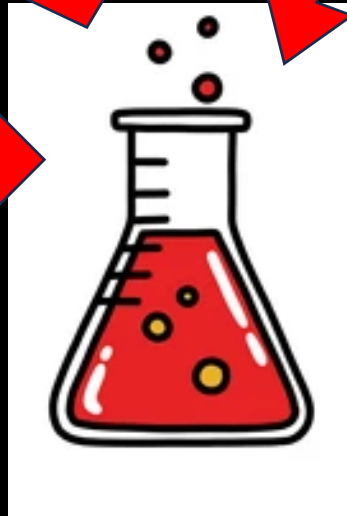
Pheromones

Root volatiles

(Undergoing)

Yeast

as a CO₂ source



Wireworms attractant

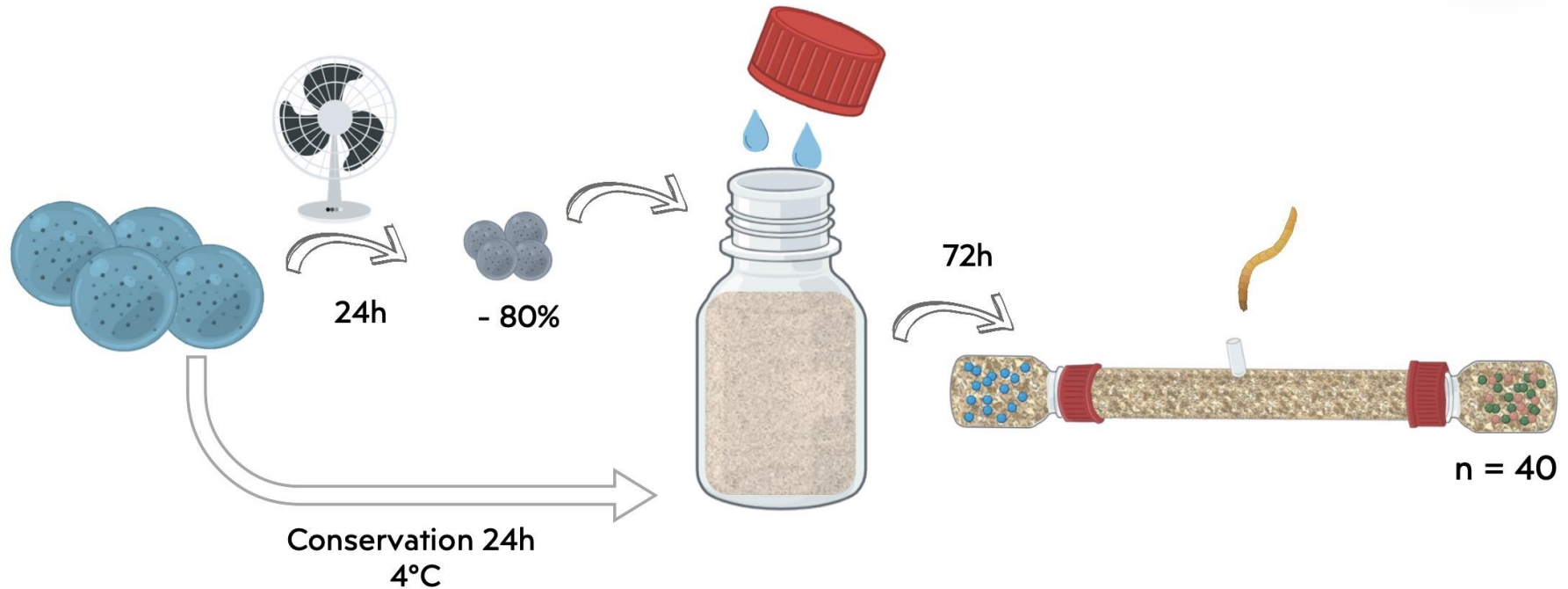


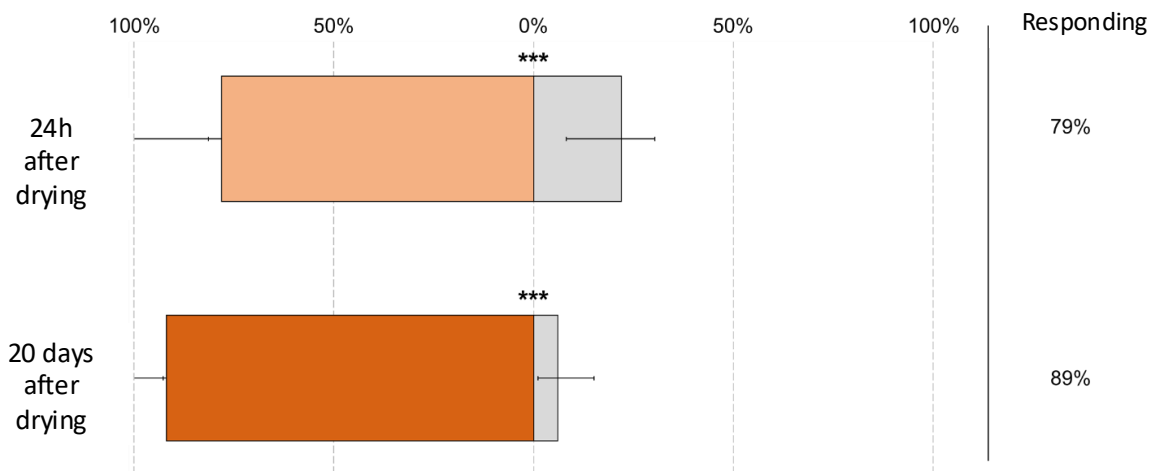


Can we dry out our formulation ?
(and keeping it attractive for wireworms)



Fanny Ruhland





Optimising the attractant

- Kairomones
- Plant extracts
- Pheromones

Optimising the microbial killer

- Entomopathogenic nematodes
- Entomopathogenic fungi

Side effects on non target species

- Ground beetles
- Ants
- Earthworms

Testing the formulation outside the laboratory

- Sugar beet fields



Development of an Attract-&Kill formulation

Attractant



Nematodes



Fungi



Development of an Attract-&Kill formulation



Fanny Ruhland

June 2nd

5.15 pm

Nematodes

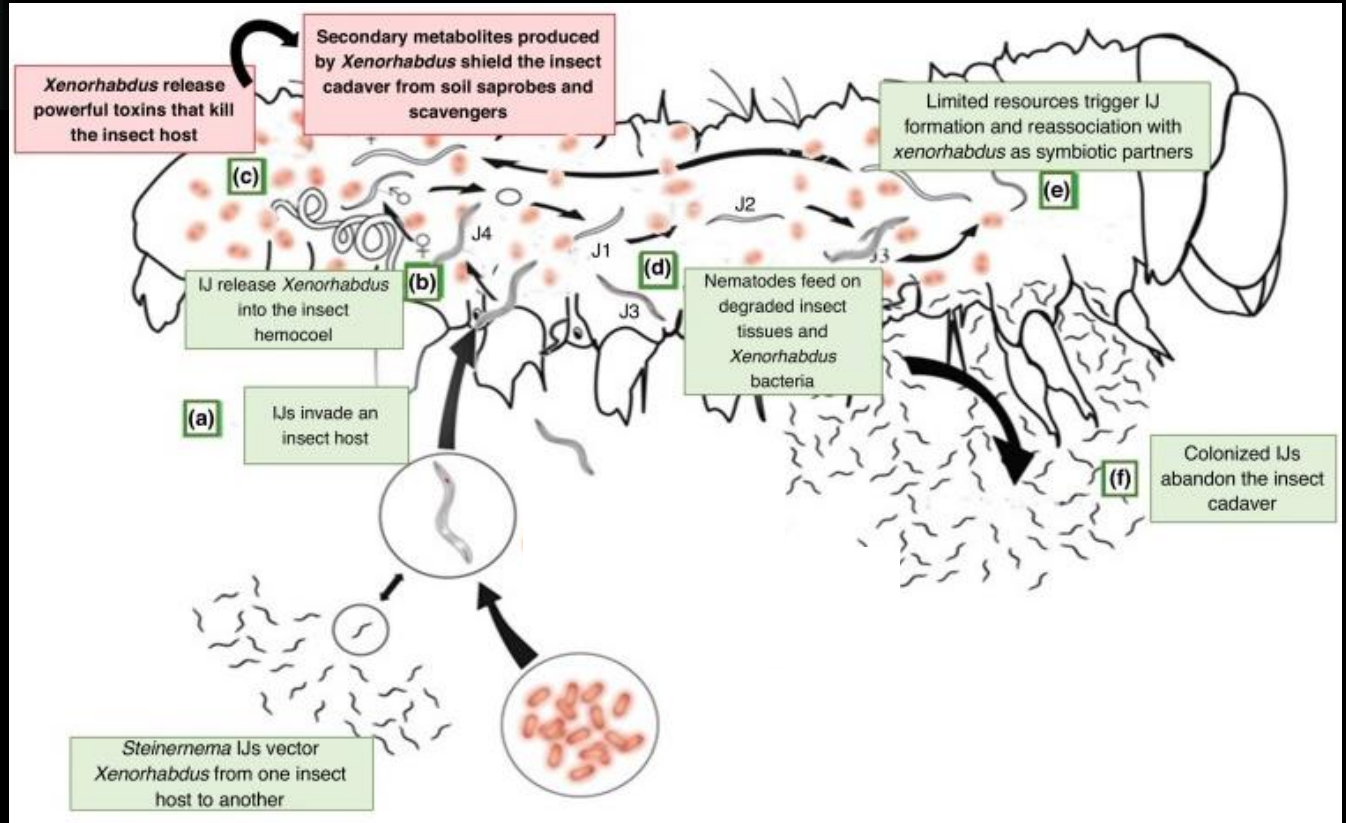


Fungi





Entomopathogenic nematodes (*S. carpocapsae* ; *H. bacteriophora*)



But wireworms are knights in plate armor ...



Sclerotized and rigid integument

Thick intersegmental membranes

Rectal muscles
that close completely the anus

Dense brush of branched hairs



To be a good killer: Evaluation of morphometry and nematodes-bacteria complex effect on entomopathogenic nematodes virulence against wireworms

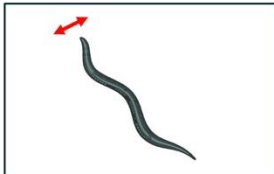
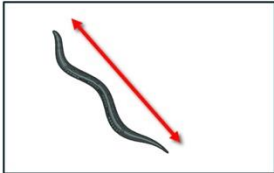
Andrea Chacon-Hurtado^a, Fanny Ruhland^a, Salimata Drabo^a, Thibaut Smeets^a,
Brice Checconi^a, Raquel Campos-Herrera^b, François J. Verheggen^{a,*}

Effect of

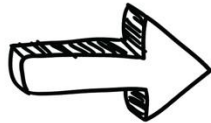
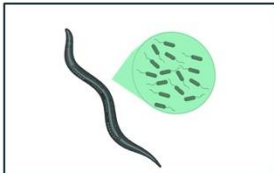
Population

Steinernema affine
Steinernema carpocapsae
Steinernema feltiae
Steinernema poinari
Heterorhabditis atacamensis
Heterorhabditis bacteriophora

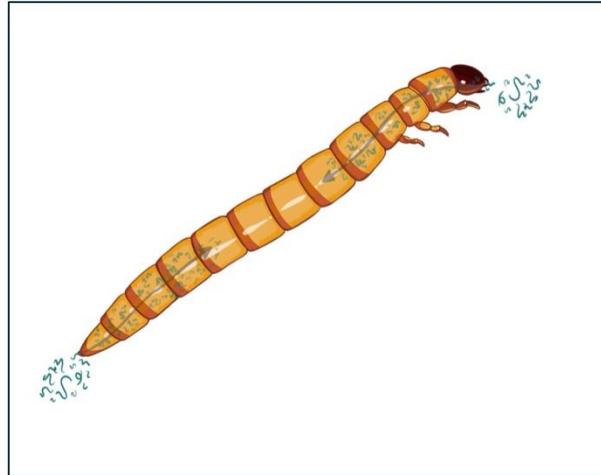
Morphometry



Symbiotic bacteria



Wireworm mortality



To be a good killer: Evaluation of morphometry and nematodes-bacteria complex effect on entomopathogenic nematodes virulence against wireworms

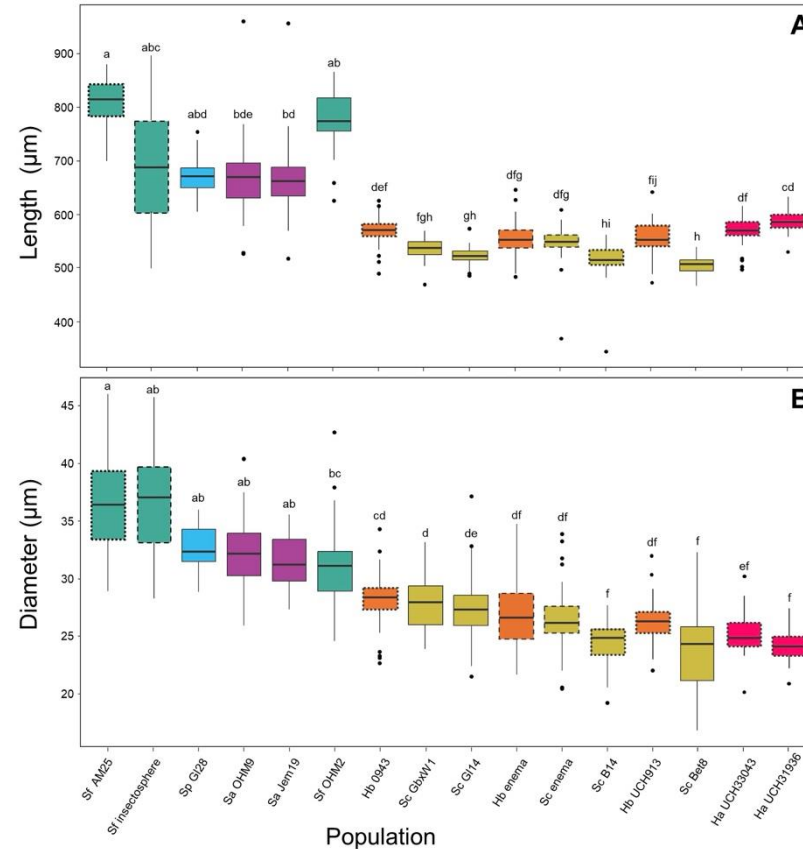
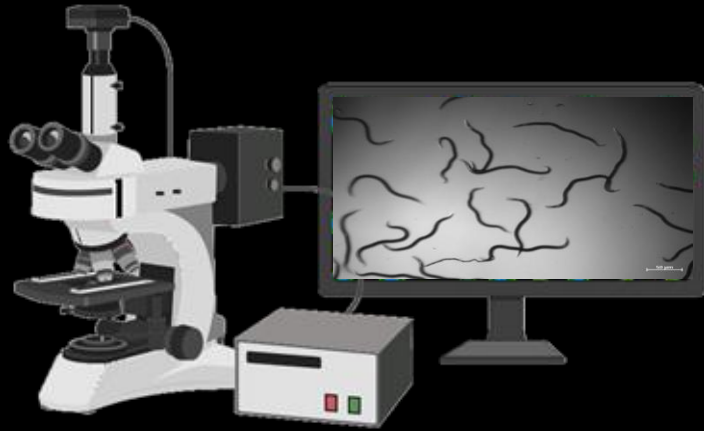
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EPN species	Geographic origine	Population	ITS- sequence (GenBank accession number)	Symbiont bacteria	16S- sequence (GenBank accession number)
<i>Steinernema affine</i>	Belgium	Sa Jem19	PP375812	<i>Xenorhabdus bovienii</i>	PP209855
	Belgium	Sa OHM9	PP375815	<i>Xenorhabdus bovienii</i>	PP209857
	Belgium	Sc Bet8	PP375816	<i>Xenorhabdus nematophila</i>	PP209849
<i>Steinernema carpocapsae</i>	Belgium	Sc GbxW1	PP375813	<i>Xenorhabdus nematophila</i>	PP209853
	Belgium	Sc GI14	PP375817	<i>Xenorhabdus nematophila</i>	PP209859
<i>Steinernema feltiae</i>	Belgium	Sf OHM2	PP375814	<i>Xenorhabdus bovienii</i>	PP209851
<i>Steinernema poinari</i>	Belgium	Sp GI28	PP375818	<i>Xenorhabdus bovienii</i>	PP209860
<i>Steinernema carpocapsae</i>	Spain	Sc B14	PQ199401	<i>Xenorhabdus nematophila</i>	PP401689
<i>Steinernema feltiae</i>	Portugal	Sf AM25	MG551674	<i>Xenorhabdus bovienii</i>	PP401693
<i>Heterorhabditis atacamensis</i>	Chile	Ha UCH-31936	MZ676563	<i>Photorhabdus antumapuensis</i>	MZ676562
	Chile	Ha UCH-33043	*	<i>Photorhabdus antumapuensis</i>	PQ198615
<i>Heterorhabditis bacteriophora</i>	Spain	Hb 0943	PQ199402	<i>Photorhabdus thracensis</i>	PP401697
	Chile	Hb UCH-913	*	<i>Photorhabdus thracensis</i>	OR140086
<i>Steinernema carpocapsae</i>	Commercial	Sc enema	PQ199403	<i>Xenorhabdus nematophila</i>	PP401691
<i>Steinernema feltiae</i>	Commercial	Sf Insectos- phere	PQ199505	<i>Xenorhabdus bovienii</i>	PP401687
<i>Heterorhabditis bacteriophora</i>	Commercial	Hb enema	PQ199404	<i>Photorhabdus laumondii</i> subsp. <i>laumondii</i>	PP401695



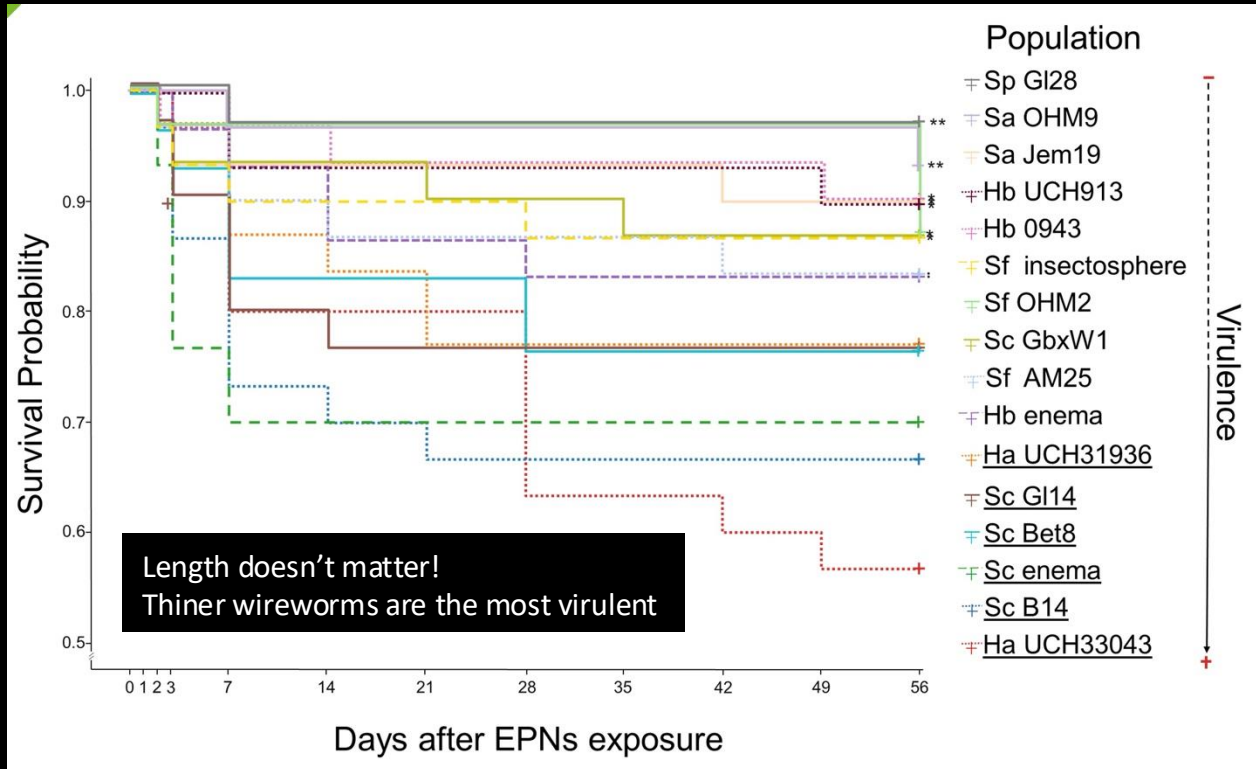
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EPNs

Symbiotic bacteria

H. bacteriophora enema



P. laumondii

H. bacteriophora 0943

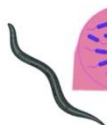
H. bacteriophora UCH 913



P. thracensis

H. atacamensis UCH 936

H. atacamensis UCH 936



P. antumapuensis

S. carpocapsae



X. nematophila

S. affine

S. feltiae

S. poinari



X. bovienii

Nematode-bacteria complex :

There was **no significant effect of nematode-bacteria complex and biochemical profile** on wireworms' mortality.

Development of an Attract-&Kill formulation

Attractant



Plant extracts & root volatiles

Nematodes



Heterorhabditis atacamensis

Fungi



*Discover the
selected species in
Fanny's talk*

Optimising the attractant

- Kairomones
- Plant extracts
- Pheromones

Optimising the microbial killer

- Entomopathogenic nematodes
- Entomopathogenic fungi

Side effects on non target species

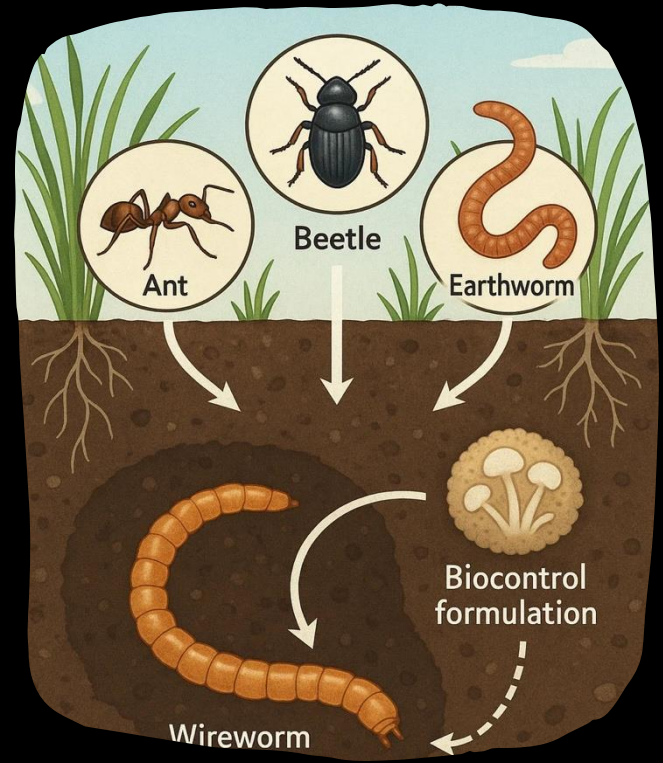
- Ground beetles
- Ants
- Earthworms

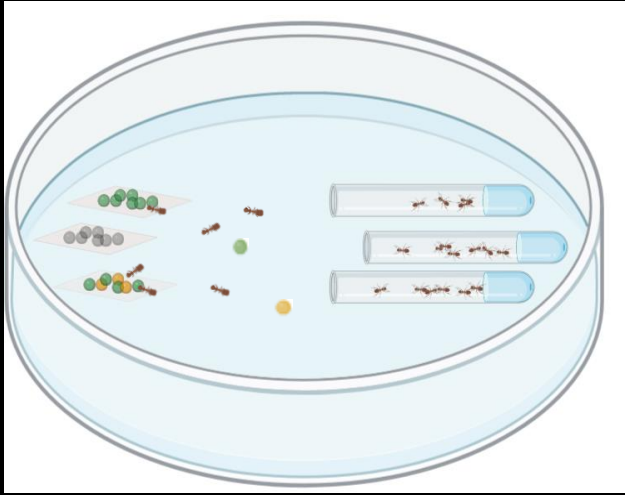


Lethal & Sublethal effects

Testing the formulation outside the laboratory

- Sugar beet fields

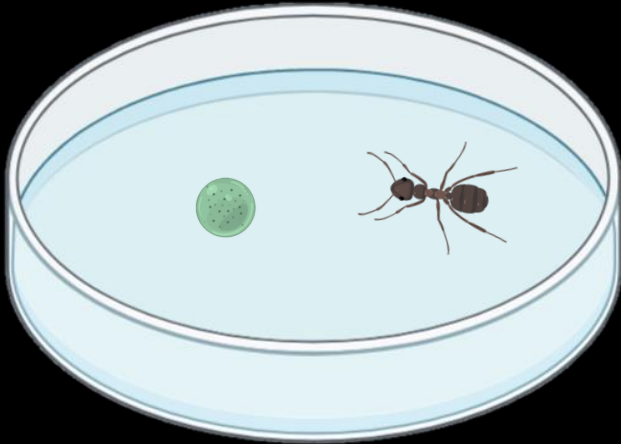




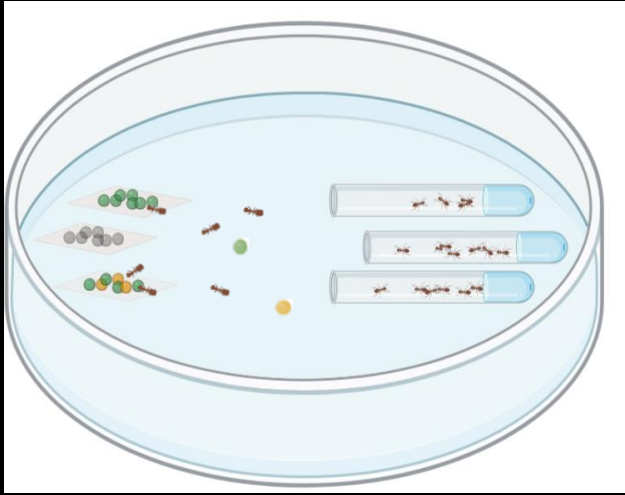
Behavioural tests



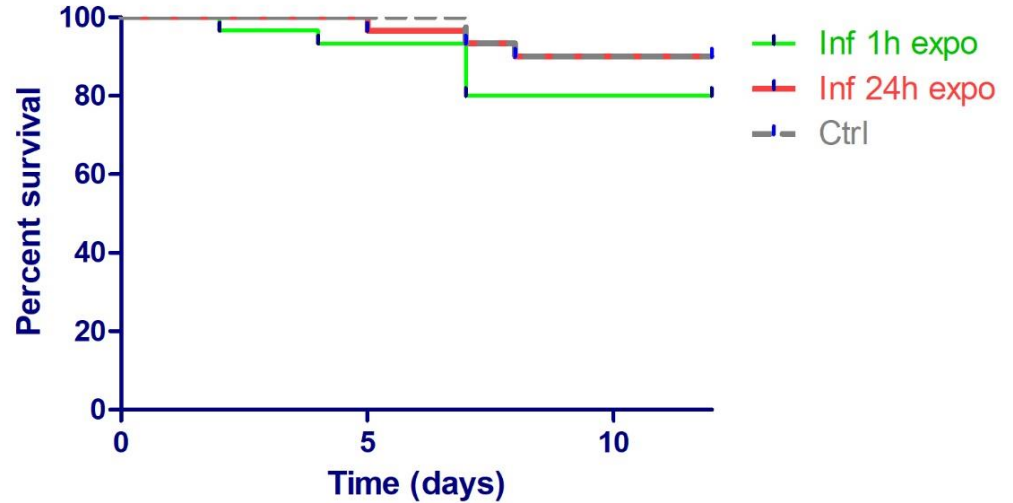
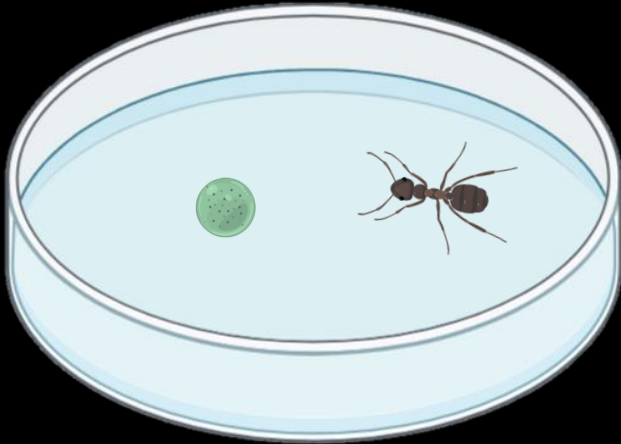
Prof Claire Detrain



Toxicity tests



No attraction
No mortality

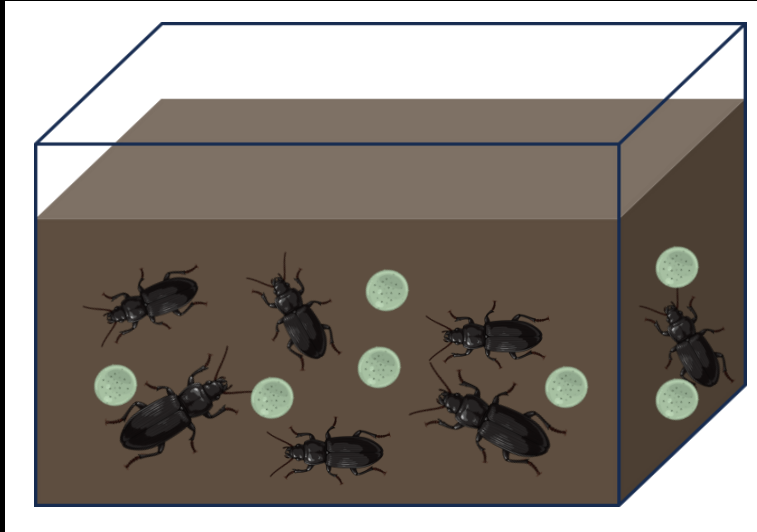




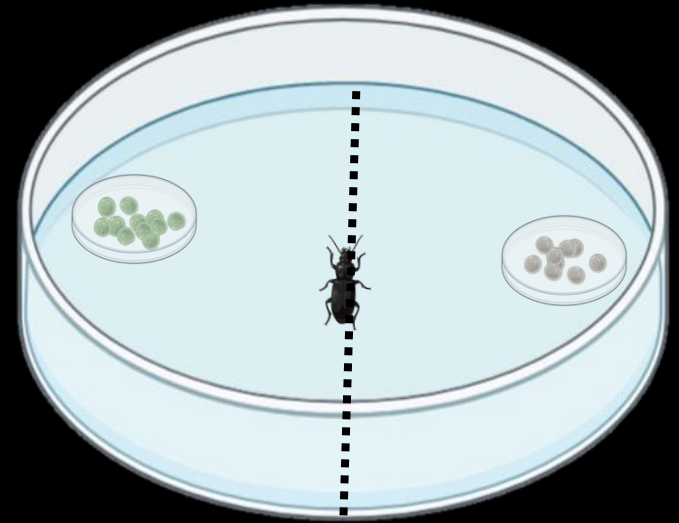
Fanny Ruhland

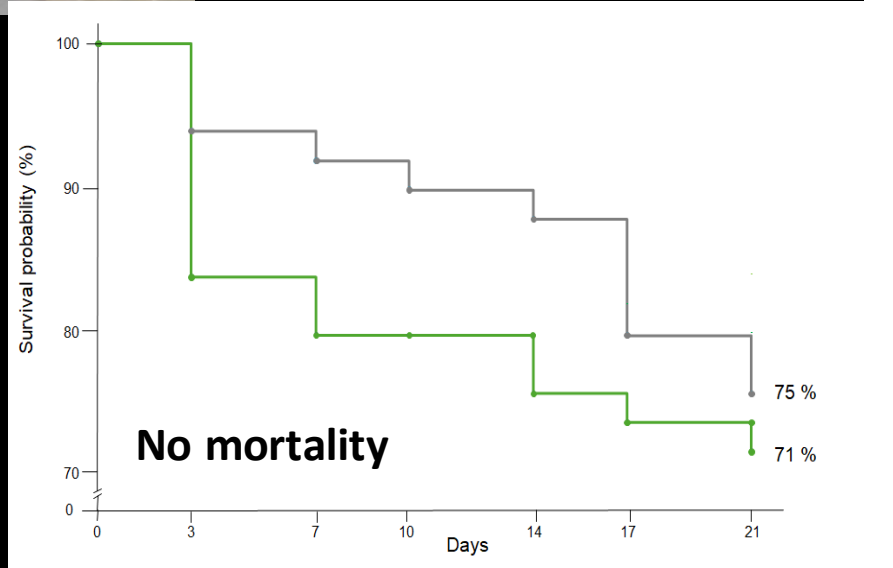
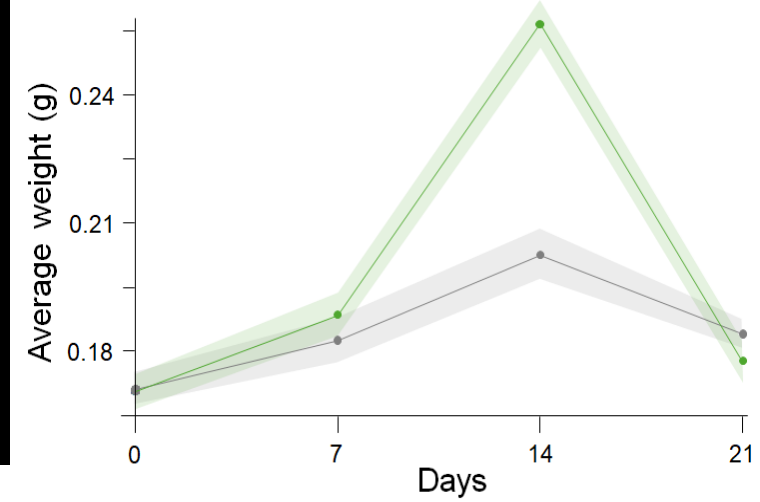
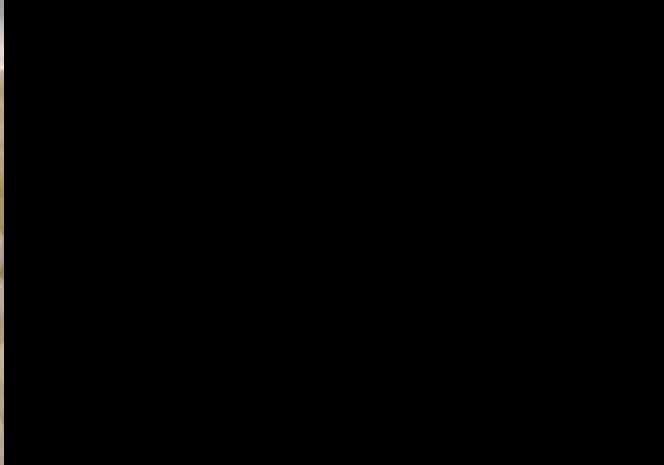


Toxicity tests



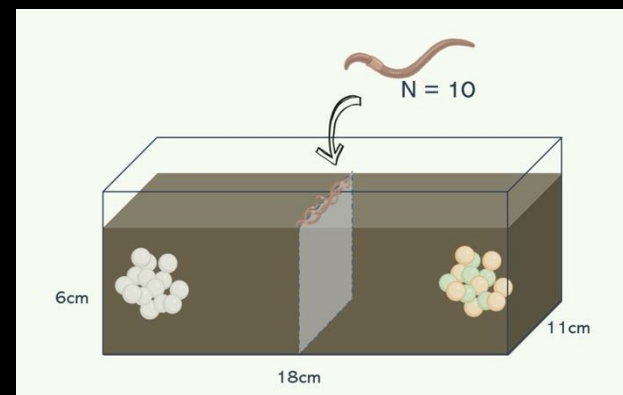
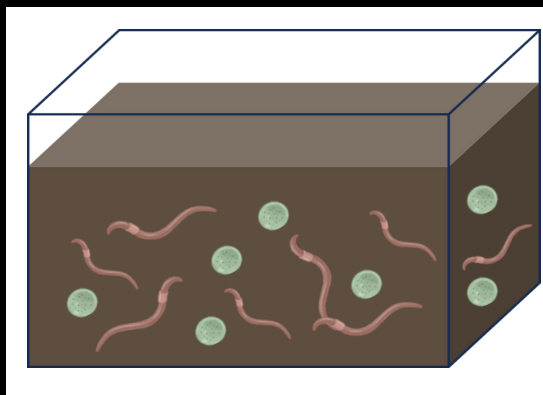
Behavioural tests





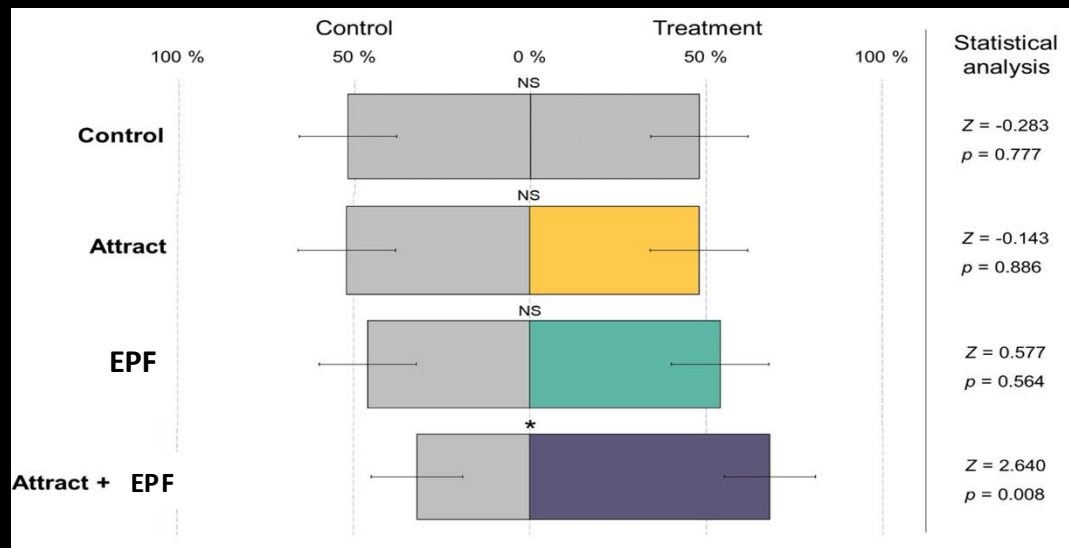
The fungi negatively impacts beetles' weight

A yellow triangular warning sign with a black border and a black exclamation mark in the center.



No mortality

Attraction
toward the
formulation



Optimising the attractant

- Kairomones
- Plant extracts
- Pheromones

Optimising the microbial killer

- Entomopathogenic nematodes
- Entomopathogenic fungi

Side effects on non target species

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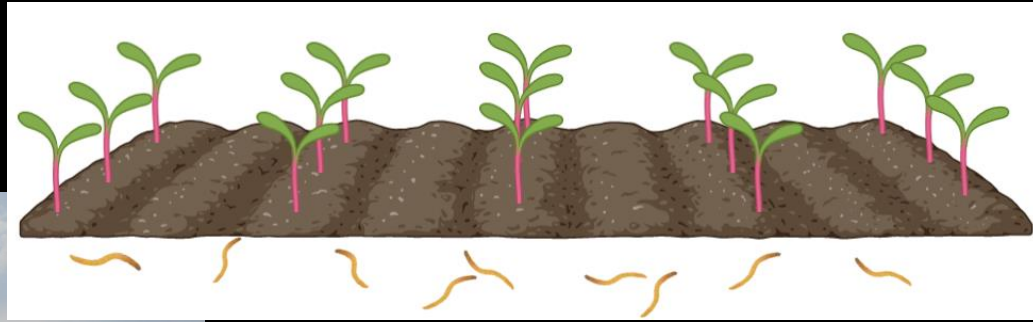
Testing the formulation outside the laboratory

- Sugar beet fields





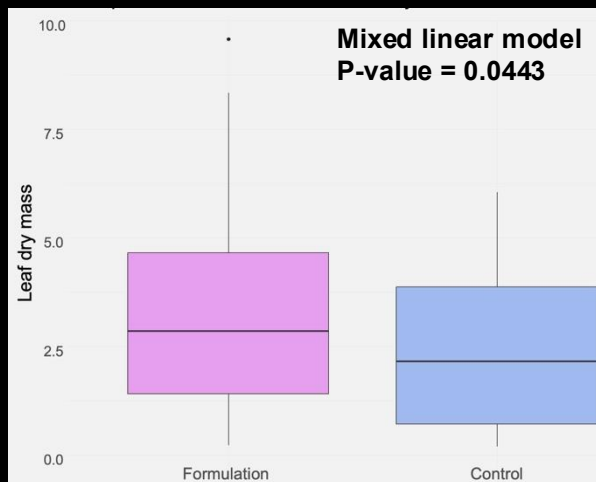
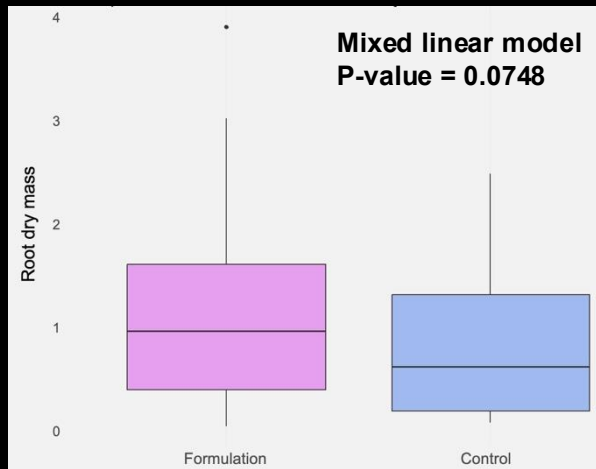
Fanny Ruhland



Fungus + attractant

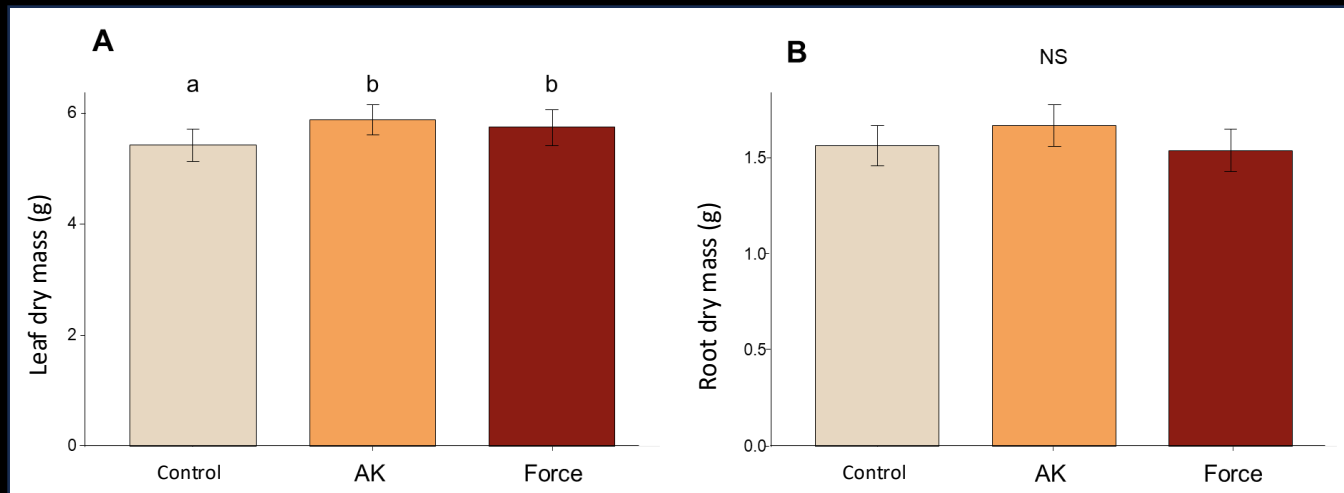


Field year 1



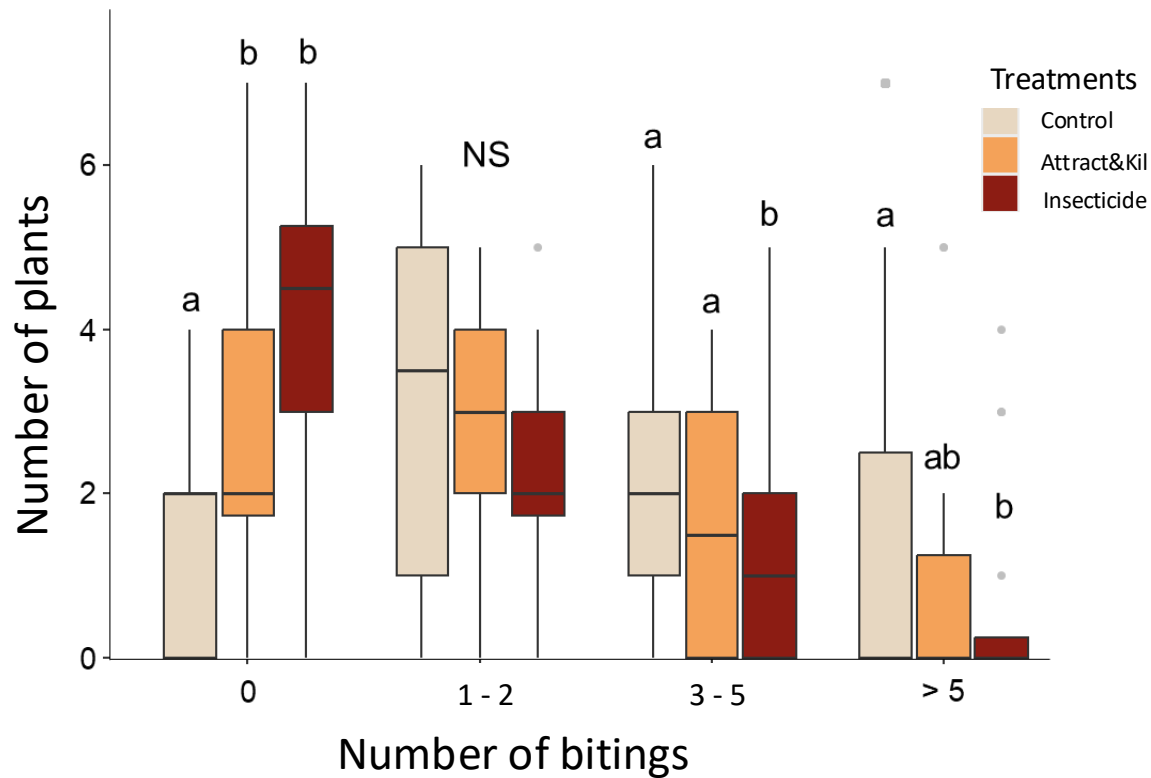
⇒ The A&K formulation leads to higher leaf dry mass

Field year 2



⇒ The A&K formulation leads to higher leaf dry mass

Field year 2



⇒ The A&K formulation reduces the number of wireworm bites as efficiently as the insecticide

Acknowledgments



Fanny Ruhland

June 2nd

5.15 pm



Stéphane Declerck



Jean-Baptiste Thibord



Raquel Campos Herrera



Outsmarting wireworms

Combining semiochemicals and entomopathogens for sustainable management



Prof François Verheggen

Gembloux Agro-Bio Tech - Université de Liège

