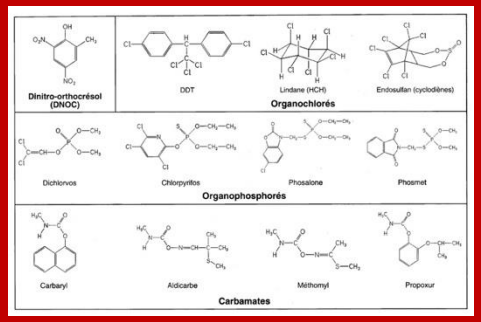
# Alternatives aux insecticides

Prof François Verheggen
Gembloux Agro-Bio Tech - Université de Liège

# Alternatives aux insecticides

## Acte I

Le problème

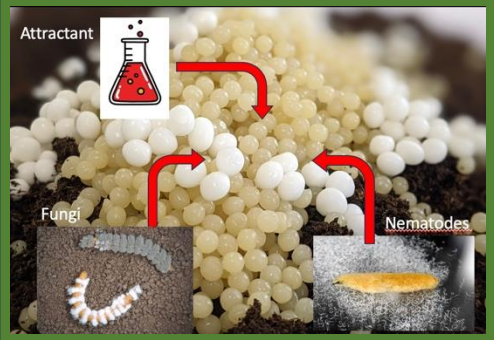



## Acte II

Les solutions

## Acte III

Notre contribution



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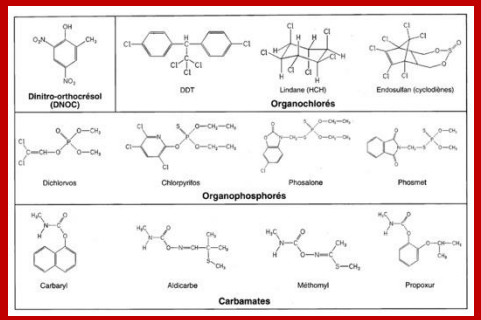


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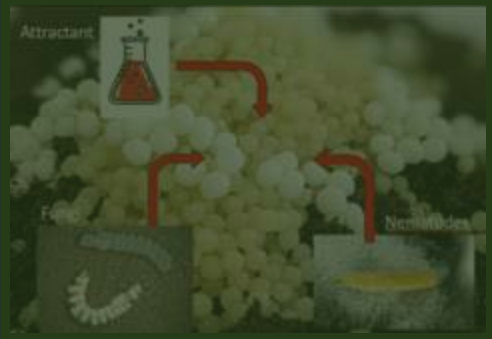
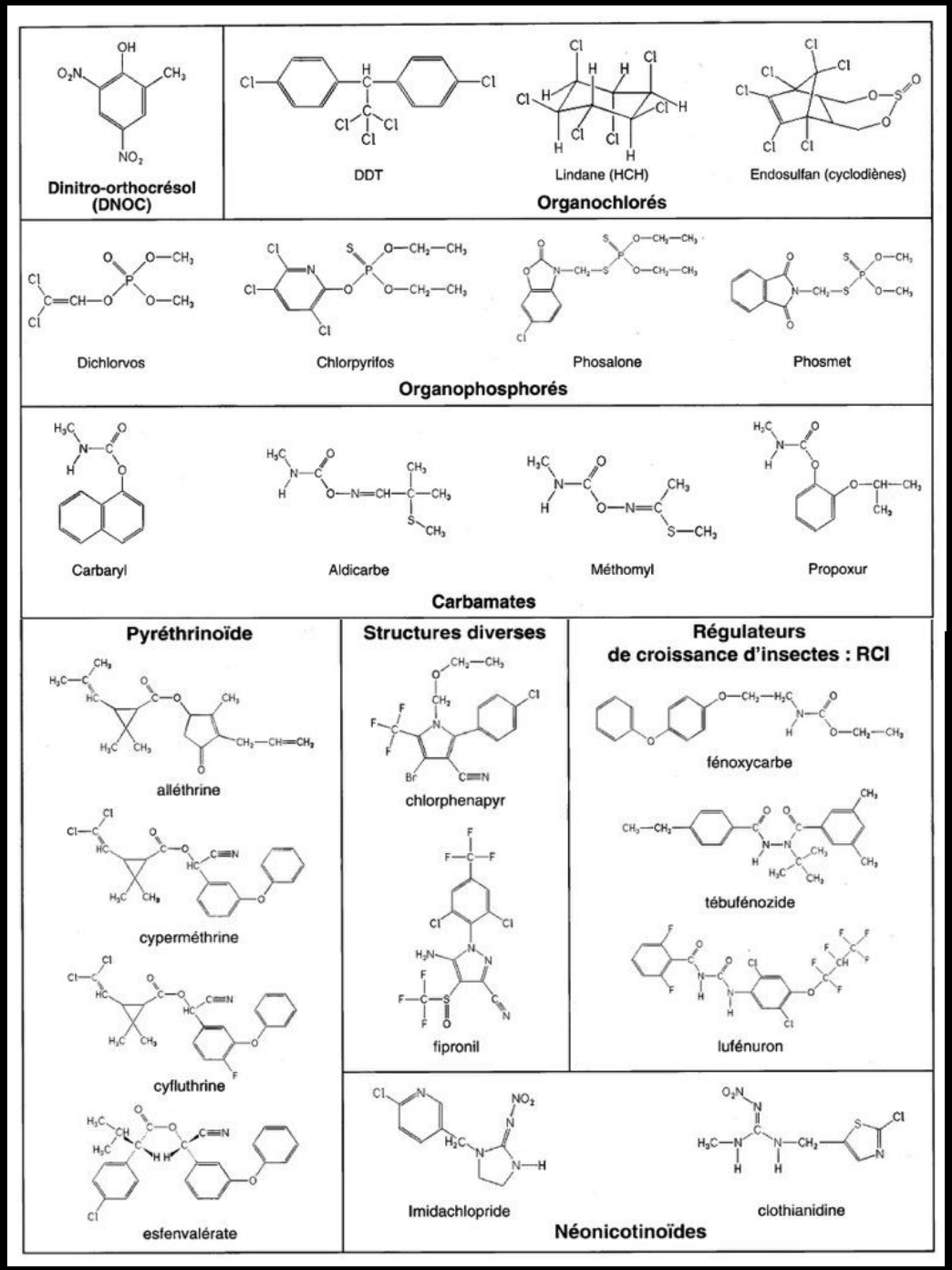
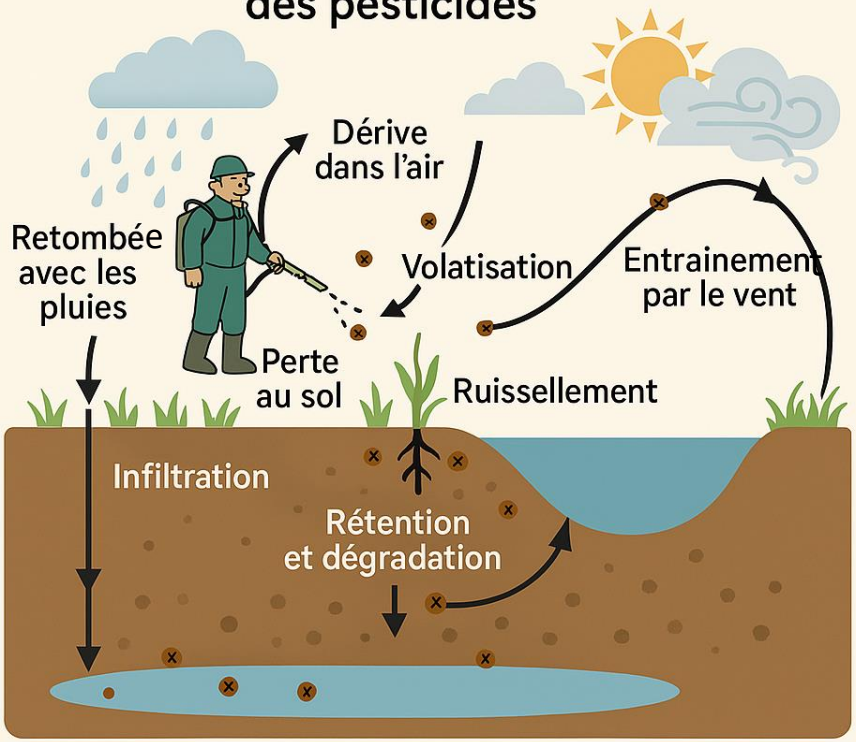





L'inventivité humaine en termes de protection des végétaux est grande

## Principaux parcours environnementaux de dissémination des pesticides




## Rappel de Aldi

06.09.2024

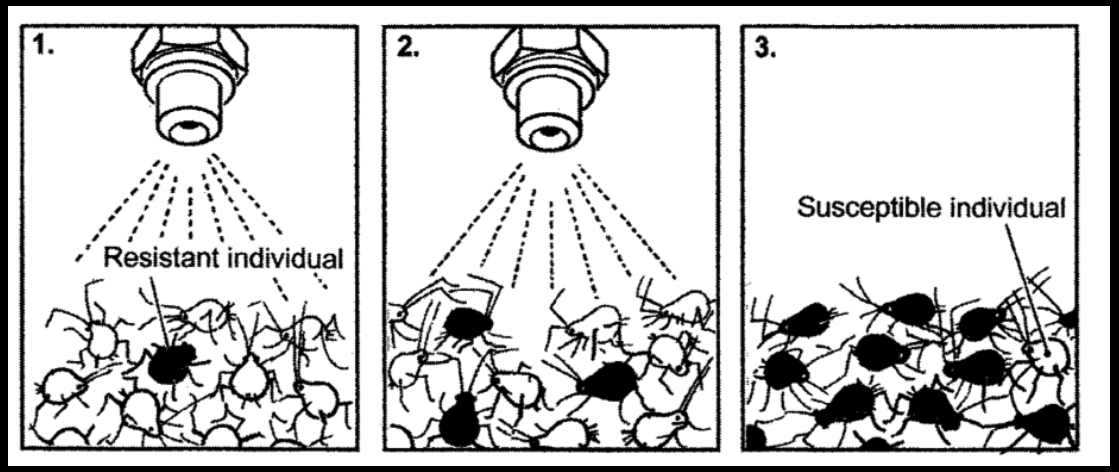
Aldi®

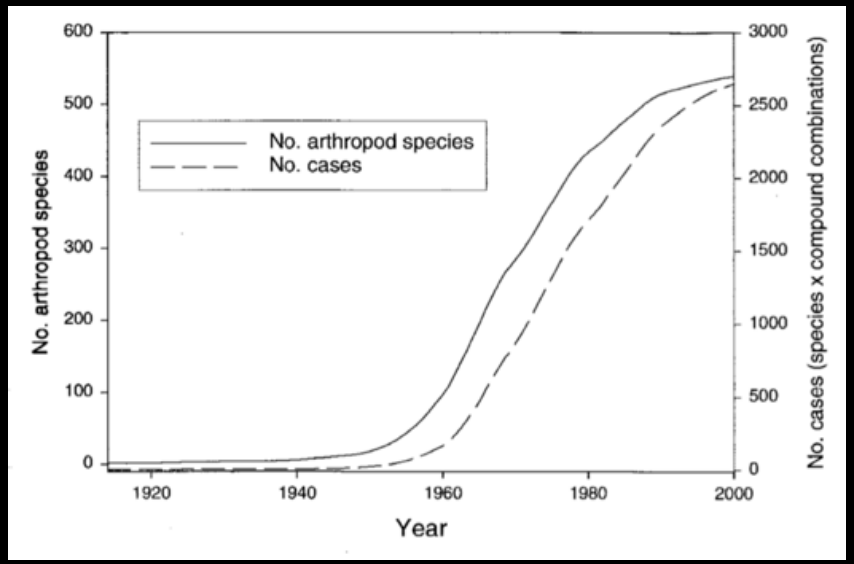
Bio Courgettes


De l'heptachlore dans des courgettes Bio

afsca

.be




insects
MDPI
Review

## Insecticide Resistance and Management Strategies in Urban Ecosystems

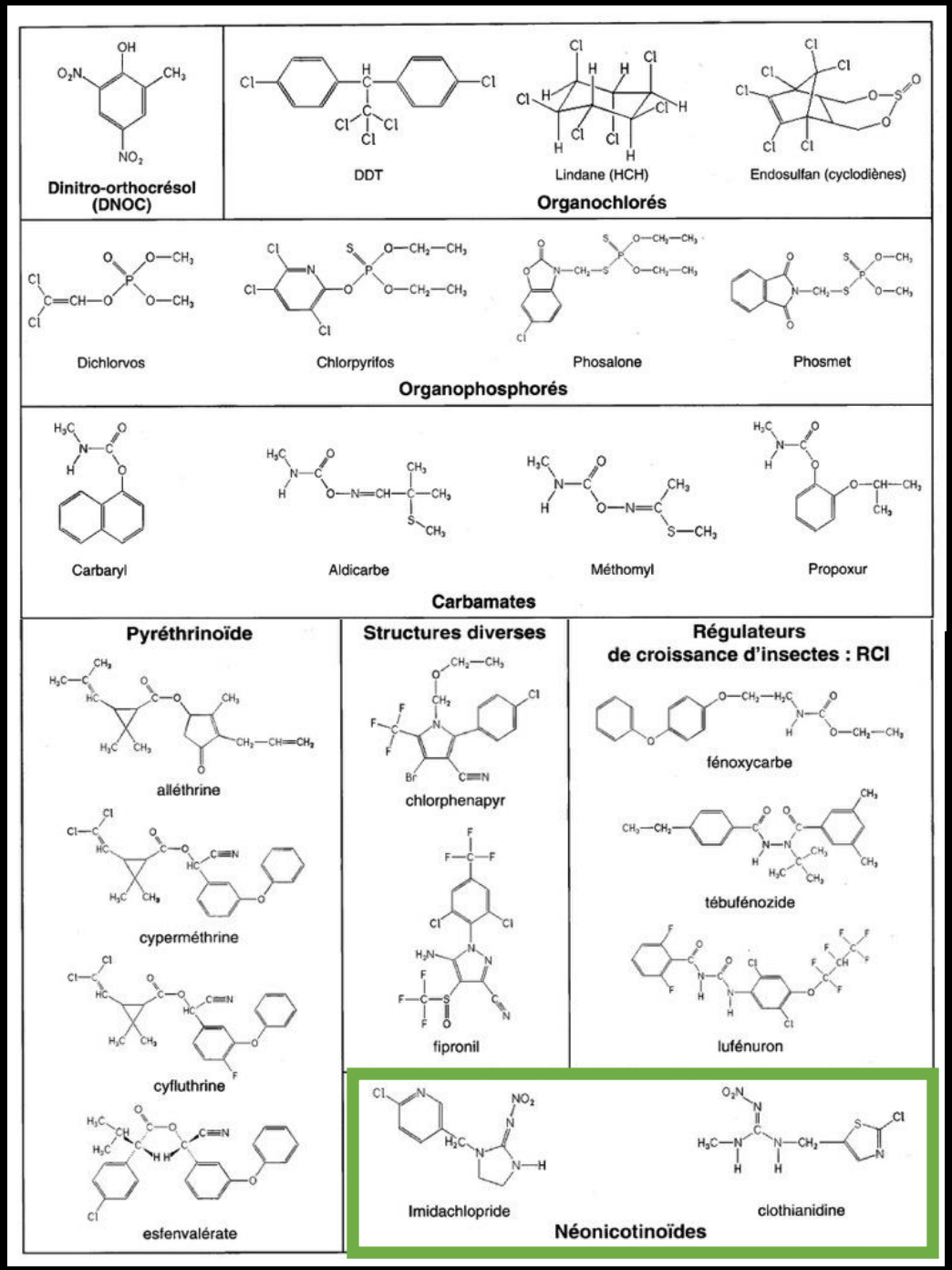
Fang Zhu [1,2,*], Laura Lavine [2], Sally O'Neal [1], Mark Lavine [2], Carrie Foss [3] and Douglas Walsh [1]

**Table 1.** Top 20 resistant arthropods in agricultural and urban ecosystems [7] (permitted kindly by Drs. Mark Whalon and David Mota-Sanchez).

| Rank | Common Name | Scientific Name | Number * | Ecosystem |
|---|---|---|---|---|
| 1 | Two-spotted spider mite | *Tetranychus urticae* | 94 | Agricultural |
| 2 | Diamondback moth | *Plutella xylostella* | 92 | Agricultural |
| 3 | Green peach aphid | *Myzus persicae* | 76 | Agricultural |
| 4 | House fly | *Musca domestica* | 62 | Urban |
| 5 | Colorado potato beetle | *Leptinotarsa decemlineata* | 55 | Agricultural |
| 5 | Sweetpotato whitefly | *Bemisia tabaci* | 55 | Agricultural |
| 7 | Southern cattle tick | *Rhipicephalus microplus* | 50 | Agricultural |
| 8 | Cotton aphid | *Aphis gossypii* | 49 | Agricultural |
| 9 | Corn bollworm | *Helicoverpa armigera* | 48 | Agricultural |
| 9 | European red mite | *Panonychus ulmi* | 48 | Agricultural |
| 11 | German cockroach | *Blattella germanica* | 42 | Urban |
| 12 | Southern house mosquito | *Culex quinquefasciatus* | 40 | Urban |
| 13 | Beet armyworm | *Spodoptera exigua* | 38 | Agricultural |
| 13 | Oriental leafworm moth | *Spodoptera litura* | 38 | Agricultural |
| 15 | House mosquito | *Culex pipiens pipiens* | 36 | Urban |
| 16 | Yellow fever mosquito | *Aedes aegypti* | 35 | Urban |
| 16 | Tobacco budworm | *Heliothis virescens* | 35 | Agricultural |
| 18 | Hop aphid | *Phorodon humuli* | 34 | Agricultural |
| 19 | Red flour beetle | *Tribolium castaneum* | 33 | Urban |
| 20 | African cotton leafworm | *Spodopotera littoralis* | 30 | Agricultural |

* Number of active ingredients to which the pest has exhibited documented resistance.

# Neonicotinoids – the particular case of sugar beets




Human inventiveness when it comes with insect pest control…


"The most widely used insecticides"

# Neonicotinoids – a (very) brief history

In 2012, science came with strong evidence…



Neonicotinoids are “highly persistent in the environment, such as substantial residues are commonly found in soils, wild flowers, streams, and lakes”

- Goulson et al. (2018) Science

# Neonicotinoids – a (very) brief history

Science

2021

LETTER

## EU Court to rule on banned pesticide use

YAFFA EPSTEIN , GUILLAUME CHAPRON, AND FRANÇOIS VERHEGGEN

SCIENCE • 16 Jul 2021 • Vol 373, Issue 6552 • p. 290 • DOI: 10.1126/science.abj9226

Consulter le journal

Le Monde

January 23rd, 2023

## Néonicotinoïdes : la France n'autorisera plus l'usage du pesticide dans les champs de betteraves sucrières

La Cour de justice de l'Union européenne avait jugé illégales les dérogations octroyées pour l'usage des pesticides interdits. Une décision « suffisamment puissante pour ne pas instabiliser encore plus le système », a reconnu le ministre de l'agriculture.

Le Monde avec AFP

Publié le 23 janvier 2023 à 18h40, modifié le 23 janvier 2023 à 19h57 · Lecture 1 min.

LE SOIR

Publié le 19/10/2023

## La Belgique ne peut plus permettre les dérogations aux pesticides

Le Conseil d'Etat a suivi l'arrêt de la Cour européenne de justice et annule les dérogations qui permettaient aux betteraviers d'utiliser des semences enrobées de ce pesticide interdit au niveau européen depuis 2018.

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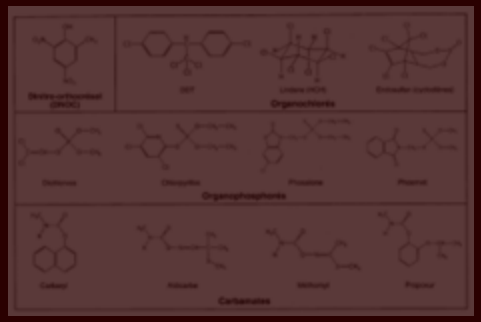

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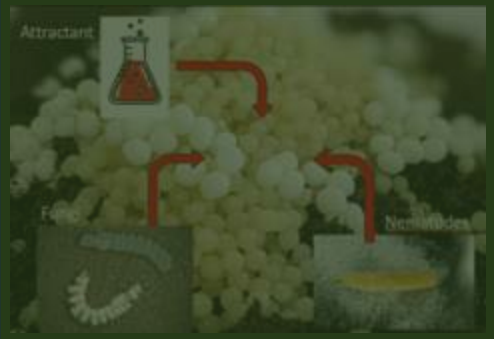

# Neonicotinoids – what alternatives ?

Agricultural practises

Varietal selection

Macroorganisms

Microorganisms

Physical means

Semiochemicals

Plant elicitors

Other biocides

Evaluation of the alternative in terms of :

- Efficacy
- Applicability
- Durability
- Practicability
- ~~Cost~~

Contents lists available at ScienceDirect

Environment International

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

2019

Alternatives to neonicotinoids

Hervé Jactel[a,*], François Verheggen[b], Denis Thiéry[c], Abraham J. Escobar-Gutiérrez[d], Emmanuel Gachet[e], Nicolas Desneux[f], the Neonicotinoids Working Group[1]

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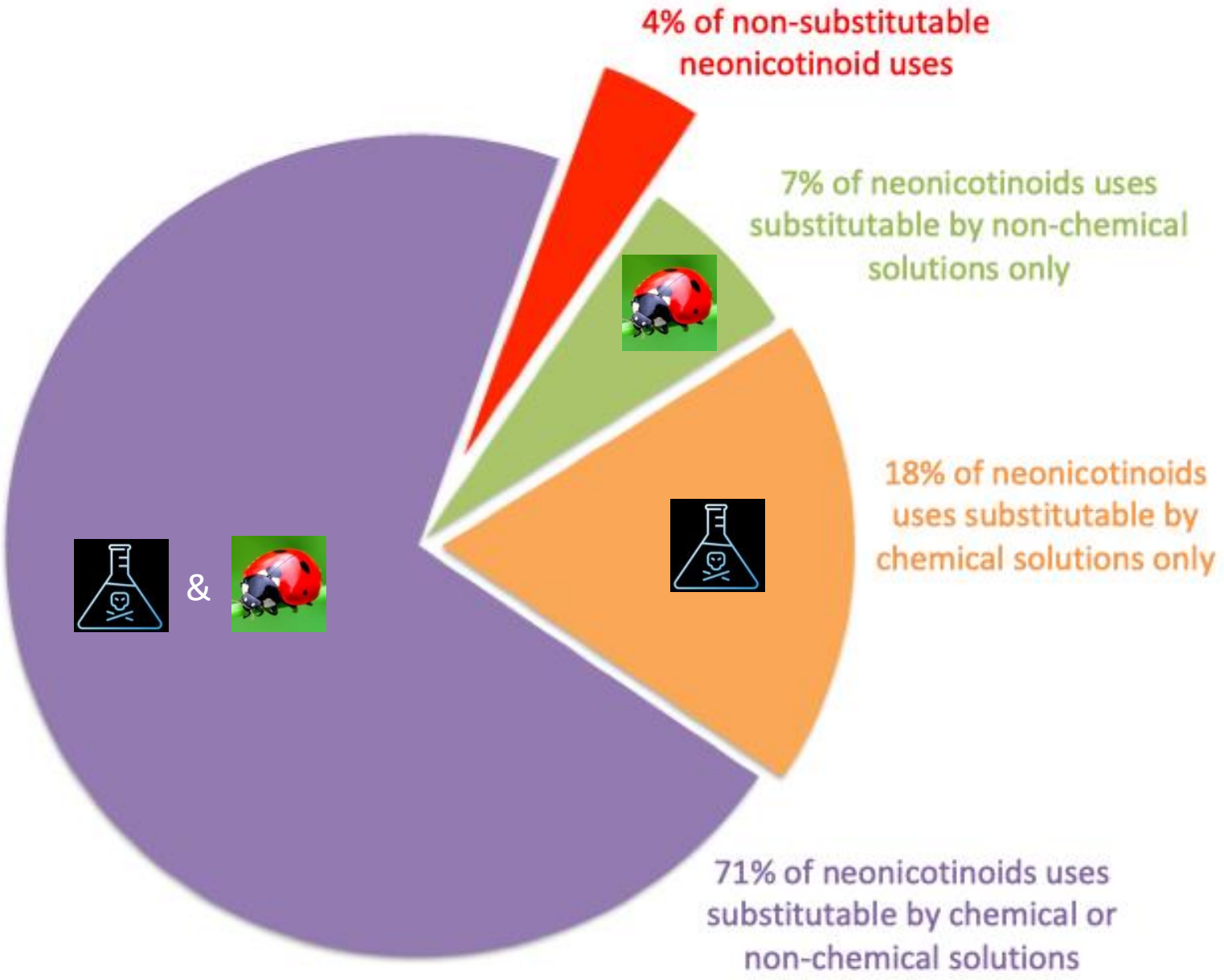
Open Access
Review Article

**Producing sugar beets without neonicotinoids: An evaluation of alternatives for the management of viruses-transmitting aphids**

2022

François Verheggen[1,*], Benoit Barrès[2], Romain Bonafos[3], Nicolas Desneux[4], Abraham J. Escobar-Gutiérrez[5], Emmanuel Gachet[6], Jérôme Laville[7], Myriam Siegwart[8], Denis Thiéry[9], and Hervé Jactel[10]




Jactel, Verheggen *et al.* 2019

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| Natural insecticides | Spinosad | 2 | 2 | 2 | 2 |
| Microorganisms | *Beauveria bassiana* | 2 | 3 | 2 | 2 |
| Microorganisms | *Lecanicillium muscarium* | 2 | 3 | 2 | 2 |
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| Farming practices | Intercropping & service plants | 2 | 3 | 2 | 1 |

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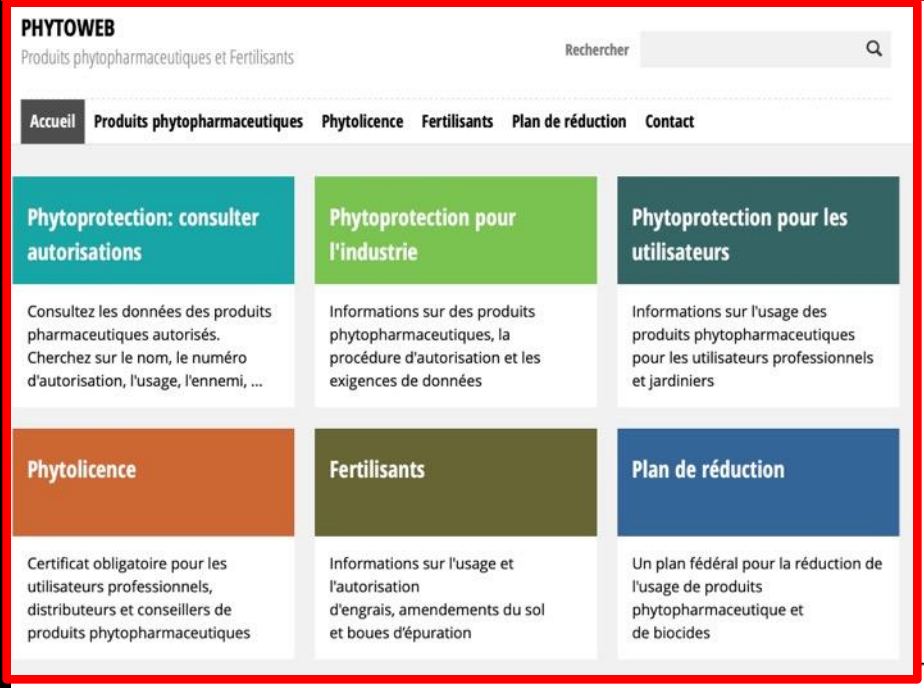

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| | | 2 | 3 | 2 | 2 |
| | | 2 | 3 | 2 | 2 |
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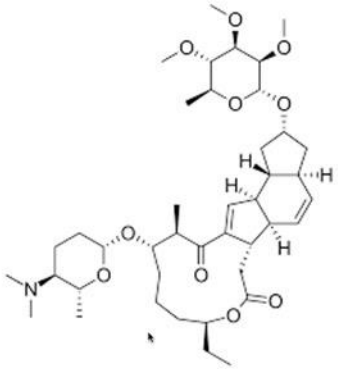
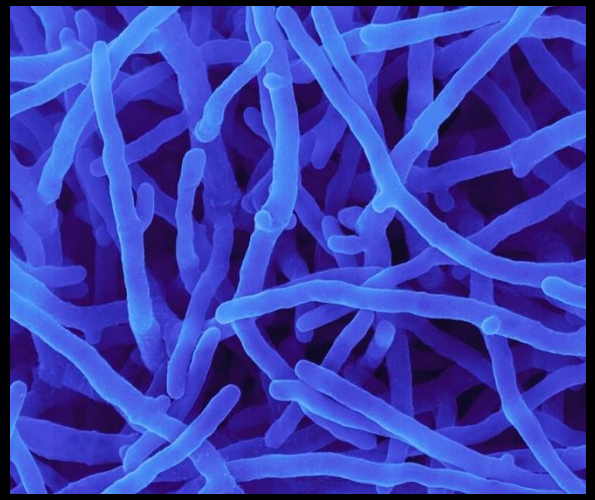
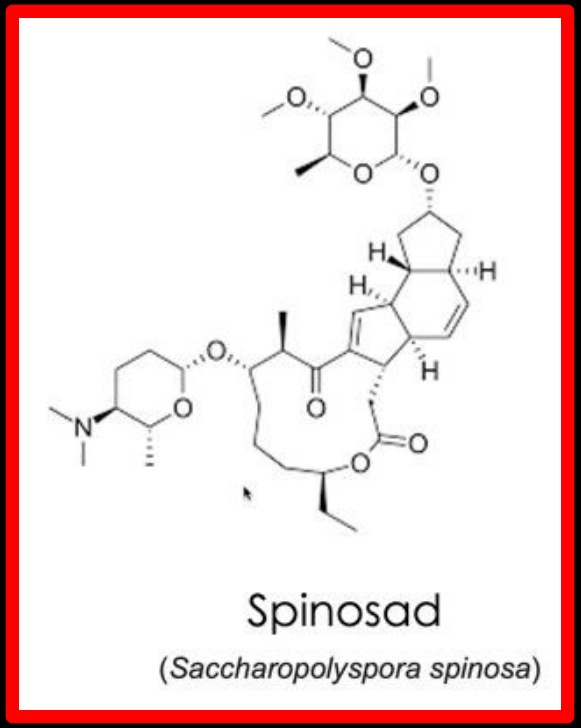


Spinosad

(*Saccharopolyspora spinosa*)



spinosyne A et D




- Extracted from *Saccharopolyspora spinosa*
- Larvicide, 'natural' neurotoxin
- Authorized since 2008
- Approved for use in organic farming
- Acts by contact and ingestion

**BUT**

**Spinosad is extremely toxic to bees** (Agroscope, Switzerland)

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| | | 2 | 3 | 2 | 3 |
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| | | 2 | 3 | 3 | 3 |
| | | 2 | 3 | 2 | 1 |

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| Farming practices | Intercropping & service plants | 2 | 3 | 2 | 1 |

## FresaProtect

*Un cocktail de six espèces différentes de micro-guêpes parasitant les pucerons des fraises.*

VIRIDAXIS PROTECT | NOS ESPECES DE PARASITOÏDES | PBI | CONTACT | VIRIDAXIS | TEMOIGNAGES

# BASILPROTECT – contre les pucerons des herbes aromatiques

***Pour les producteurs d'herbes dans les cultures protégées, BasilProtect est la solution optimale pour contrôler les pucerons.***



*Tetranychus urticae*


*Phytoseiulus persimilis*

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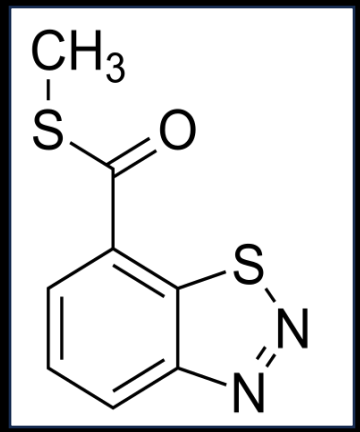
# Acibenzolar-S-méthyl

First stimulator of plant natural defenses (Syngenta-USA)

Induction of natural defenses

- VOCs
- Phytotoxins
- Antifeedants
- Phytodefenses



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| | | 2 | 2 | 2 | 2 |
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| | *n muscarium* | 2 | 3 | 2 | 2 |
| | | 3 | 3 | 2 | 2 |
| | *carnea* | 2 | 3 | 2 | 2 |
| | | 2 | 3 | 2 | 3 |
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# Producing sugar beets without neonicotinoids: An evaluation of alternatives for the management of viruses-transmitting aphids

**Table 1.** The twenty short-term (immediate or next few years) alternative methods/products to neonicotinoid-coated beet seeds, along with their respective scores of efficacy, durability, applicability and practicability (1=low, 2=average, 3=good).

| Categories of alternatives | Alternative methods | Efficacy | Durability | Applicability | Practicity |
|---|---|---|---|---|---|
| | | 3 | 2 | 3 | 3 |
| | | 2 | 3 | 3 | 3 |
| | | 2 | 3 | 2 | 3 |
| | zoate | 2 | 2 | 2 | 3 |
| | | 2 | 2 | 2 | 3 |
| | l oil | 2 | 3 | 2 | 3 |
| | rachtin | 2 | 3 | 2 | 3 |
| | | 2 | 2 | 2 | 2 |
| | *ana* | 2 | 3 | 2 | 2 |
| | *uscarium* | 2 | 3 | 2 | 2 |
| | | 3 | 3 | 2 | 2 |
| | *nea* | 2 | 3 | 2 | 2 |
| | | 2 | 3 | 2 | 3 |
| | | 2 | 3 | 2 | 3 |
| | nethyl | 2 | 3 | 2 | 3 |
| | | 2 | 3 | 2 | 3 |
| | arieties | 2 | 3 | 2 | 3 |
| Farming practices | Mulching | 2 | 3 | 3 | 2 |
| Farming practices | Organic fertilization | 2 | 3 | 3 | 3 |
| Farming practices | Intercropping & service plants | 2 | 3 | 2 | 1 |

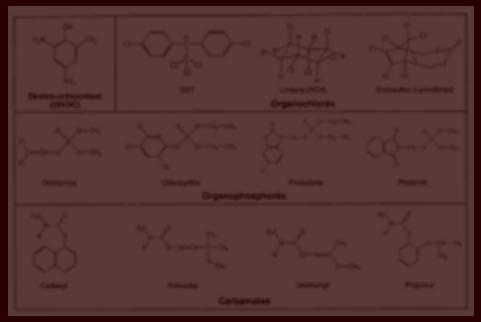
# Pratiques culturales



# Alternatives aux insecticides

## Acte I

Le problème

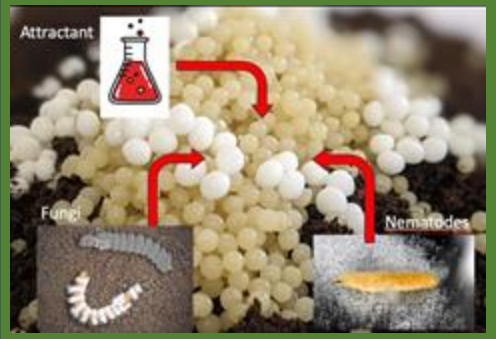


## Acte II

Les solutions

## Acte III

Notre contribution



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# TRANS-PEST

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## Today's target

## Wireworms

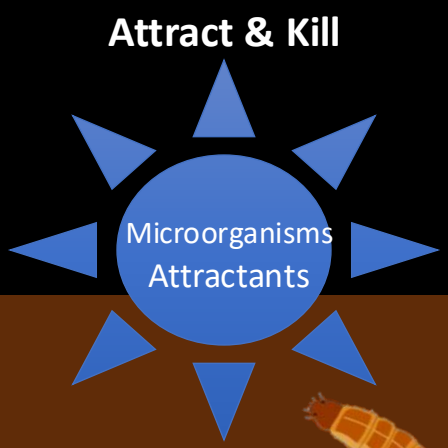
(Agriotes sp., Coleoptera, Elateridae)

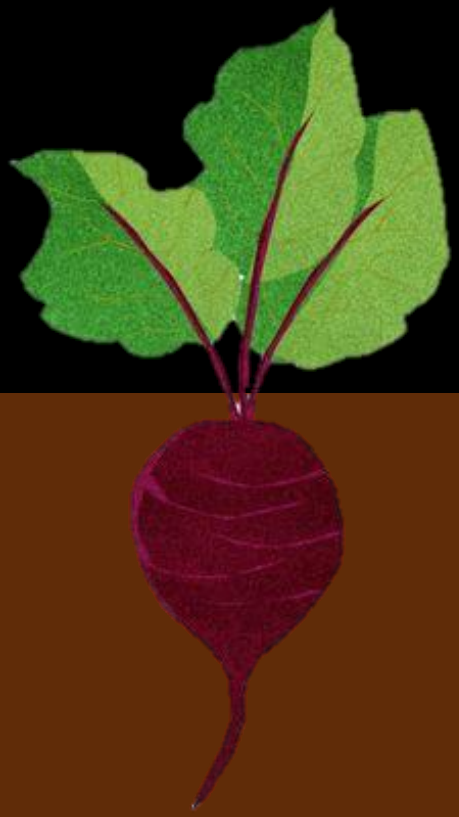
# TRANS-PEST

Development of an Attract-&-Kill formulation to control insect pests

**Killer agent** = entomopathogenic nematodes and fungi
**Attractants** = plant extracts and pheromones
**Formulation** = biodegradable and protective matrix

Partnership with S. Declerck (UCLouvain)



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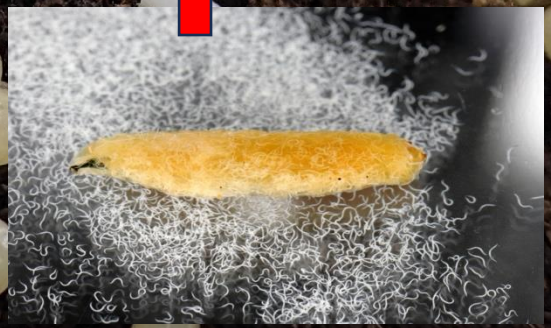
Attractant

Fungi

Nematodes



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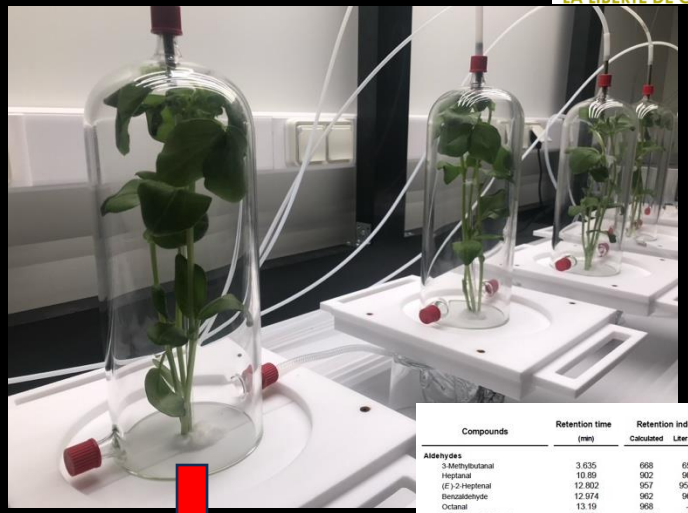

J Pest Sci
DOI 10.1007/s10340-016-0734-y

CrossMark

ORIGINAL PAPER

# Foraging wireworms are attracted to root-produced volatile aldehydes

Fanny Barsics[1] · Benjamin M. Delory[2,4] · Pierre Delaplace[2] · Frédéric Francis[1] · Marie-Laure Fauconnier[3] · Éric Haubruge[1] · François J. Verheggen[1]

| Compounds | Retention time (min) | Retention index Calculated | Retention index Literature | Quantity emitted (ng/g·h) First physiological stage Charlotte | Spunta | Monalisa |
|---|---|---|---|---|---|---|
| **Aldehydes** | | | | | | |
| 3-Methylbutanal | 3.635 | 668 | 652 | 2.0 ± 0.55 | 1.3 ± 0.21 | 1.3 ± 0.17 |
| Heptanal | 10.89 | 902 | 902 | 5.8 ± 5.2 | 2.6 ± 1.99 | 0.4 ± 0.26 |
| (*E*)-2-Heptenal | 12.802 | 957 | 956 * | -- | -- | -- |
| Benzaldehyde | 12.974 | 962 | 962 | 4.2 ± 1.4 | 1.9 ± 0.33 | 1.7 ± 0.15 |
| Octanal | 13.19 | 968 | -- | -- | -- | -- |
| Benzeneacetaldehyde | 15.821 | 1046 | 1046 | 1.1 ± 0.24 | 0.7 ± 0.29 | 0.7 ± 0.26 |
| (*E*)-2-Octenal | 16.249 | 1059 | 1060 | -- | -- | -- |
| (*E*)-4-Nonenal | 17.407 | 1094 | -- | -- | -- | -- |
| Nonanal | 17.75 | 1105 | 1103 | -- | -- | -- |
| (*E*)-2-Nonenal | 19.503 | 1161 | 1162 | 3.0 ± 2.52 | -- | -- |
| (*E,E*)-2,4-Nonadienal | 21.171 | 1216 | 1215 | -- | -- | -- |
| (*E*)-2-Decenal | 22.566 | 1264 | 1263 | -- | -- | -- |
| **Alcohols** | | | | | | |
| 3-Methyl-1-butanol | 5.465 | 732 | 737 | 0.1 ± 0.14 | 0.1 ± 0.08 | 0.1 ± 0.07 |
| Propylene glycol | 5.52 | 734 | 734 * | 1.5 ± 0.49 | 1.3 ± 0.62 | 1.1 ± 0.67 |
| 2,3-Butanediol | 6.761 | 776 | 786 * | -- | -- | -- |
| 1-Hexanol | 9.753 | 868 | 870 | 0.2 ± 0.14 | 0.2 ± 0.09 | 0.2 ± 0.11 |
| 2-Butoxyethanol | 11.03 | 906 | 936 ** | 5.2 ± 4.2 | -- | 0.3 ± 0.31 |
| Hexylene glycol | 11.542 | 920 | 872 ** | 1.1 ± 0.25 | 1.2 ± 0.56 | 0.5 ± 0.33 |
| 1-Heptanol | 13.244 | 970 | 968 | 0.1 ± 0.06 | 0.1 ± 0.05 | 0.1 ± 0.05 |
| 1-Octen-3-ol | 13.583 | 979 | 980 | 0.7 ± 0.2 | 0.4 ± 0.15 | 0.1 ± 0.04 |
| 2-Ethyl-1-hexanol | 15.246 | 1029 | 1030 | 4.0 ± 1.38 | 2.2 ± 0.79 | 1.4 ± 0.48 |
| Benzyl alcohol | 15.443 | 1035 | 1036 | 1.3 ± 1.10 | 0.1 ± 0.10 | 0.3 ± 0.30 |
| 1-Octanol | 16.61 | 1070 | 1071 | -- | -- | -- |
| 2-Phenyl-2-propanol | 17.186 | 1088 | 1107 * | 0.5 ± 0.18 | 0.5 ± 0.47 | 0.7 ± 0.39 |
| Phenylethyl alcohol | 18.084 | 1116 | 1115 | 0.4 ± 0.10 | 0.2 ± 0.06 | 0.2 ± 0.08 |
| 1-Nonanol | 19.804 | 1171 | 1173 | 2.5 ± 0.62 | 1.3 ± 0.37 | 1.2 ± 0.39 |
| 2-Propyl-1-heptanol | 21.11 | 1214 | 1194 ** | 1.1 ± 0.24 | 1.0 ± 0.38 | 0.6 ± 0.20 |
| 2-Phenoxyethanol | 21.374 | 1223 | 1222 * | 10.4 ± 6.20 | 2.0 ± 1.97 | 1.5 ± 1.36 |
| 1-Decanol | 22.81 | 1272 | 1272 | 0.8 ± 0.32 | 0.3 ± 0.12 | 0.4 ± 0.14 |
| **Acids and carboxylic acids** | | | | | | |
| Propanoic acid | 4.456 | 697 | 706 ** | 0.05 ± 0.05 | 0.7 ± 0.67 | 1.3 ± 1.29 |
| 2-Methylpropanoic acid | 6.046 | 752 | 770 * | 2.0 ± 0.70 | 2.0 ± 0.89 | 2.1 ± 1.19 |
| 3-Methylbutanoic acid | 8.786 | 840 | 860 | 2.1 ± 1.07 | 1.6 ± 0.90 | 1.5 ± 0.84 |
| 2-Methylbutanoic acid | 9.108 | 849 | 881 * | 0.2 ± 0.21 | 0.4 ± 0.42 | 0.4 ± 0.40 |
| Pentanoic acid | 10.13 | 879 | 911 * | 0.1 ± 0.12 | 0.4 ± 0.39 | 0.3 ± 0.28 |
| **Ketones** | | | | | | |
| Butyrolactone | 11.26 | 912 | 941 * | 0.4 ± 0.19 | 0.2 ± 0.16 | 0.1 ± 0.05 |
| Pentalactone | 12.673 | 953 | 954 * | 0.2 ± 0.12 | 0.3 ± 0.11 | 0.2 ± 0.14 |
| 6-Methyl-5-hepten-2-one | 13.855 | 987 | 986 | -- | -- | -- |
| 2-Undecanone | 23.462 | 1295 | 1293 | 0.8 ± 0.41 | 0.5 ± 0.20 | 0.2 ± 0.08 |
| (*E*)-Geranylacetone | 27.815 | 1456 | 1452 | 1.9 ± 1.09 | 3.8 ± 1.57 | 2.3 ± 1.40 |
| **Alkanes and Alkenes** | | | | | | |
| Heptadecane | 33.704 | 1700 | 1700 | 2.1 ± 0.57 | 1.8 ± 0.36 | 1.5 ± 0.57 |
| Nonadecane | 37.093 | 1900 | 1900 | 7.0 ± 2.21 | 2.5 ± 0.78 | 2.2 ± 0.83 |
| Heneicosane | 38.815 | 2100 | 2100 | 4.7 ± 1.35 | 2.2 ± 0.99 | 2.3 ± 0.81 |
| **Sesquiterpenes** | | | | | | |
| Unidentified Sesquiterpene | 29.139 | 1508 | -- | 0.02 ± 0.03 | -- | 0.04 ± 0.04 |
| Unidentified Sesquiterpene | 29.405 | 1519 | -- | -- | -- | -- |
| **Aromatics** | | | | | | |
| Styrene | 10.56 | 892 | 890 | 1.1 ± 0.25 | 1.2 ± 0.56 | 0.6 ± 0.32 |
| Benzothiazole | 21.63 | 1232 | 1226 * | 2.0 ± 0.86 | 0.6 ± 0.22 | 0.5 ± 0.21 |
| Diisopropylnaphthalene 1 | 33.456 | 1689 | | 4.9 ± 1.45 | 4.6 ± 0.94 | 3.2 ± 1.48 |
| Diisopropylnaphthalene 2 | 33.58 | 1695 | | 6.8 ± 1.64 | 6.4 ± 1.04 | 4.6 ± 1.97 |
| Diisopropylnaphthalene 3 | 34.459 | 1736 | Unidentified isomers | 13.7 ± 1.95 | 13.1 ± 1.70 | 9.5 ± 3.80 |
| Diisopropylnaphthalene 4 | 34.54 | 1740 | | 6.1 ± 1.24 | 5.6 ± 0.69 | 4.1 ± 1.74 |
| Diisopropylnaphthalene 5 | 34.619 | 1744 | | 8.2 ± 1.02 | 7.0 ± 0.82 | 5.6 ± 2.24 |
| Diisopropylnaphthalene 6 | 34.717 | 1749 | | 3.2 ± 0.31 | 3.3 ± 0.51 | 2.2 ± 0.82 |
| **Amines and Amides** | | | | | | |
| Pyridine | 5.704 | 740 | 740 * | 0.5 ± 0.17 | 0.3 ± 0.13 | 0.4 ± 0.18 |
| N-Butylformamide | 17.365 | 1093 | 905 ** | -- | -- | -- |
| Methenamine | 21.583 | 1230 | 1204 ** | 0.1 ± 0.07 | 4.8 ± 4.77 | 3.4 ± 3.44 |
| **Arenes** | | | | | | |
| Ethylbenzene | 9.545 | 862 | 857 * | 3.8 ± 2.96 | 1.8 ± 1.61 | 0.1 ± 0.09 |
| **Furans** | | | | | | |
| 2-Pentylfuran | 14.04 | 993 | 992 | 0.3 ± 0.11 | 0.2 ± 0.06 | 0.2 ± 0.04 |

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Entomologia Generalis, Volume 43 (2023), Issue 6, 1193–1201
Published online November 24, 2023

Article

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

Andrea Chacon Hurtado[1], Fanny Ruhland[1], Antoine Boullis[1], François J. Verheggen[1,*]

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Arthropod-Plant Interactions
https://doi.org/10.1007/s11829-023-09958-9

ORIGINAL PAPER

# 2-Pentylfuran: an aggregation attractant for wireworms

Diana la Forgia[1,3] · Clément Martin[1] · Ted C. J. Turlings[2] · François Verheggen[1]

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Attractants

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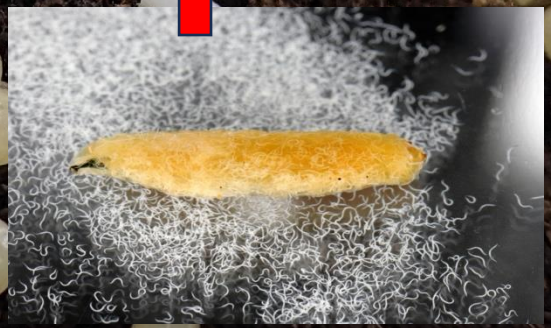
Attractant


Fungi

Nematodes



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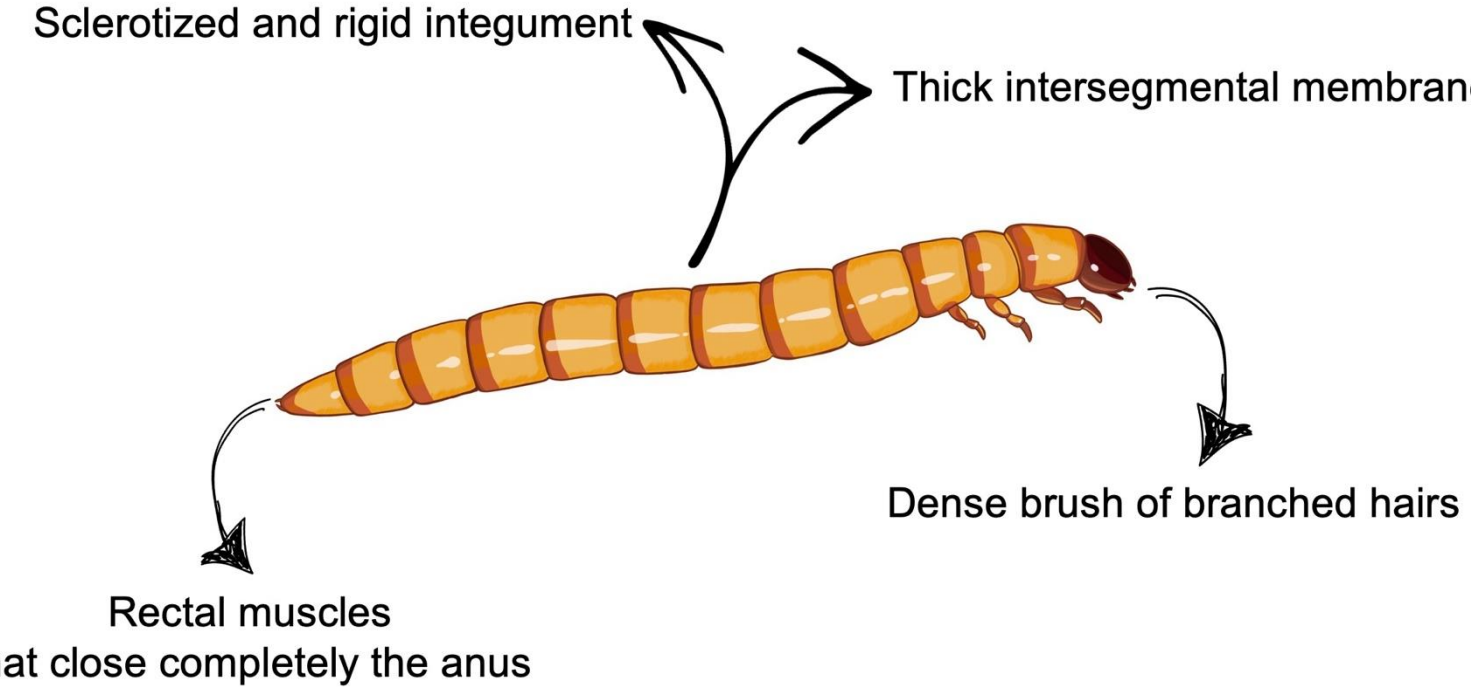


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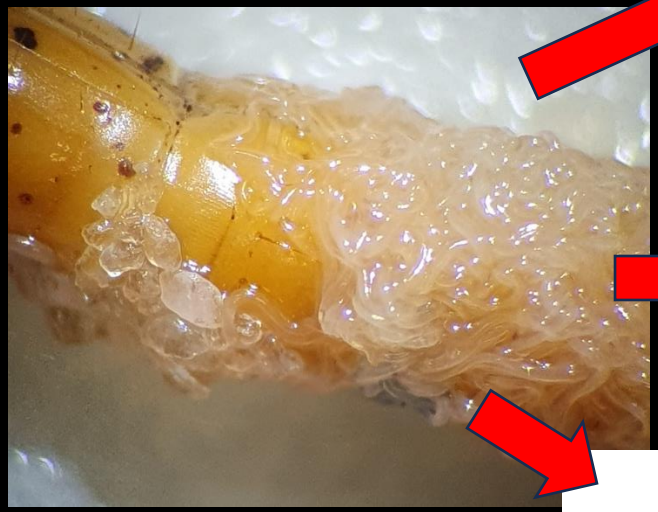
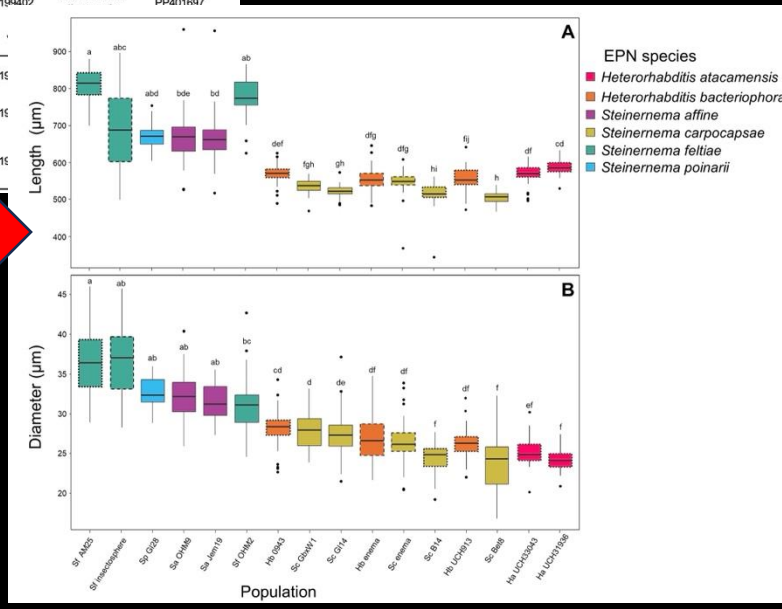
Journal of Invertebrate Pathology 207 (2024) 108231

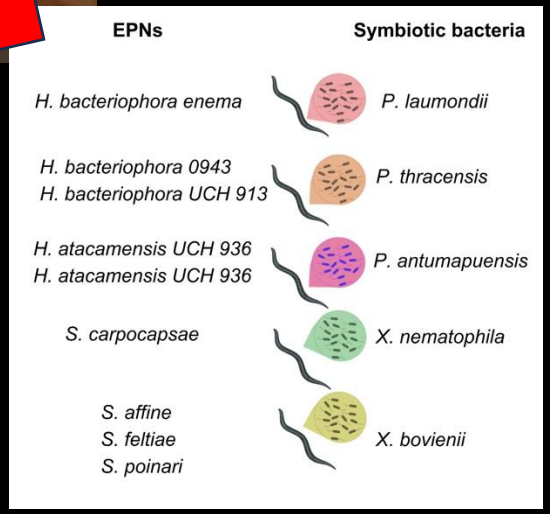
# To be a good killer: Evaluation of morphometry and nematodes-bacteria complex effect on entomopathogenic nematodes virulence against wireworms

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



| EPN species | Geographic origine | Population | ITS- sequence (GenBank accession number) | Symbiont bacteria | 16S- sequence (GenBank accession number) |
|---|---|---|---|---|---|
| *Steinernema affine* | Belgium | Sa Jem19 | PP375812 | *Xenorhabdus bovienii* | PP209855 |
| | Belgium | Sa OHM9 | PP375815 | *Xenorhabdus bovienii* | PP209857 |
| *Steinernema carpocapsae* | Belgium | Sc Bet8 | PP375816 | *Xenorhabdus nematophila* | PP209849 |
| | Belgium | Sc GbxW1 | PP375813 | *Xenorhabdus nematophila* | PP209853 |
| | Belgium | Sc Gl14 | PP375817 | *Xenorhabdus nematophila* | PP209859 |
| *Steinernema feltiae* | Belgium | Sf OHM2 | PP375814 | *Xenorhabdus bovienii* | PP209851 |
| *Steinernema poinari* | Belgium | Sp Gl28 | PP375818 | *Xenorhabdus bovienii* | PP209860 |
| *Steinernema carpocapsae* | Spain | Sc B14 | PQ199401 | *Xenorhabdus nematophila* | PP401689 |
| *Steinernema feltiae* | Portugal | Sf AM25 | MG551674 | *Xenorhabdus bovienii* | PP401693 |
| *Heterorhabditis atacamensis* | Chile | Ha UCH-31936 | MZ676563 | *Photorhabdus antumapuensis* | MZ676562 |
| | Chile | Ha UCH-33043 | * | *Photorhabdus antumapuensis* | PQ198615 |
| *Heterorhabditis bacteriophora* | Spain | Hb 0943 | PQ199402 | *Photorhabdus* | PP401697 |
| | Chile | Hb UCH-913 | | | |
| *Steinernema carpocapsae* | Commercial | Sc enema | PQ19 | | |
| *Steinernema feltiae* | Commercial | Sf Insectos-phere | PQ19 | | |
| *Heterorhabditis bacteriophora* | Commercial | Hb enema | PQ19 | | |



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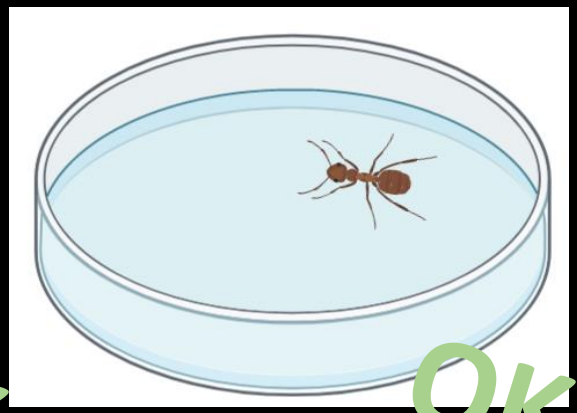
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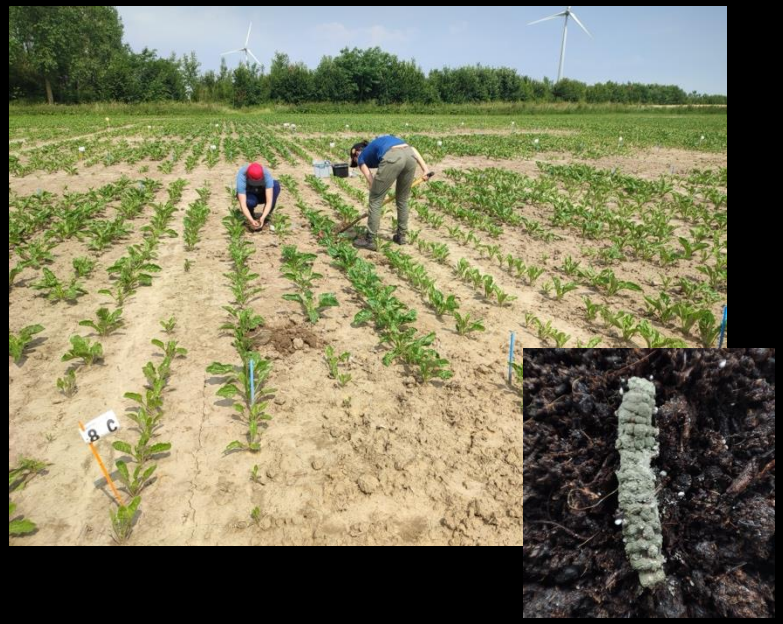



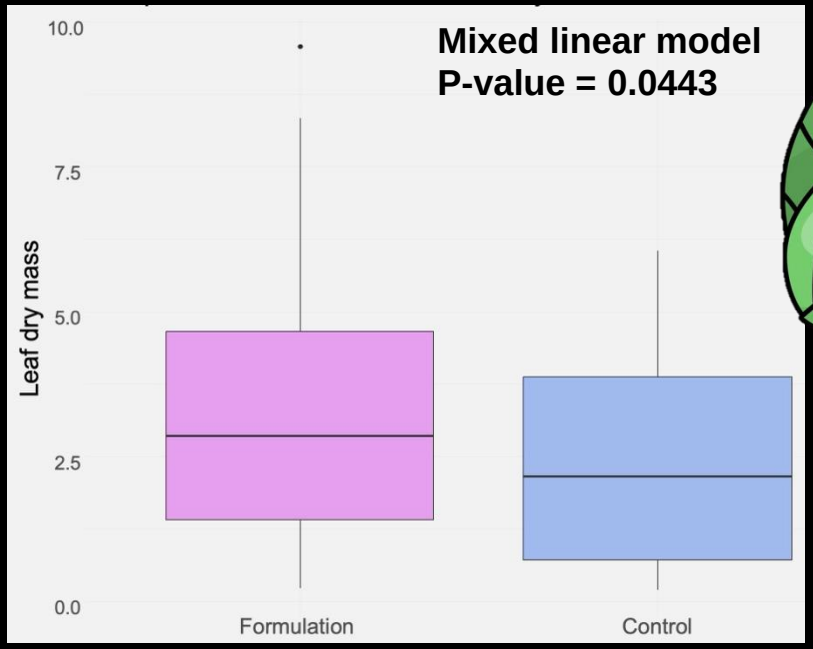


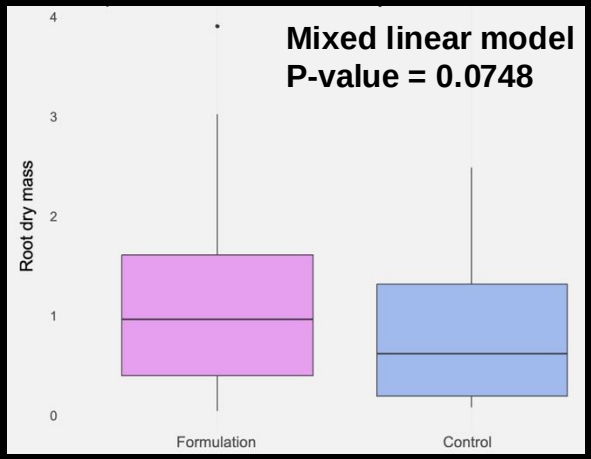


# Alternatives to neonicotinoids exist !

But they are arguably :

- Insufficient, when used alone
- Sometimes not sustainable
- More expensive
- Not completely ready