



Bioprotezione delle piante dai parassiti animali



Lucia Zappalà

Convegno AIPP

Salute delle piante tra sostenibilità e nuove sfide
Ancona – 12-14 Maggio 2025



Università
di Catania



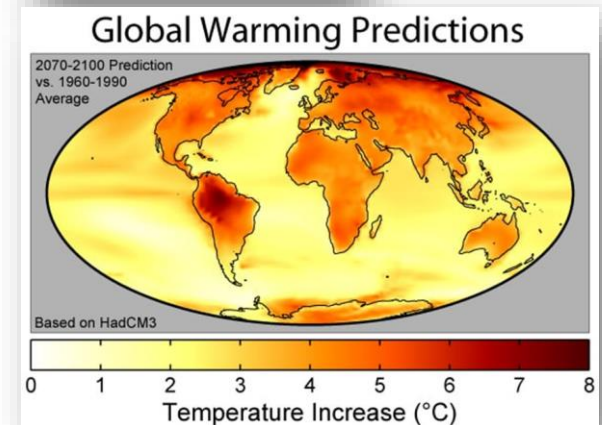
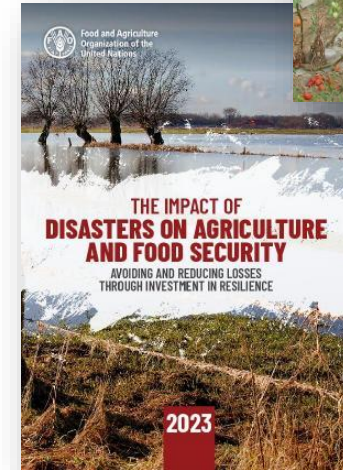
AGRICOLTURA,
ALIMENTAZIONE
E AMBIENTE



Sezione
Entomologia
Agraria

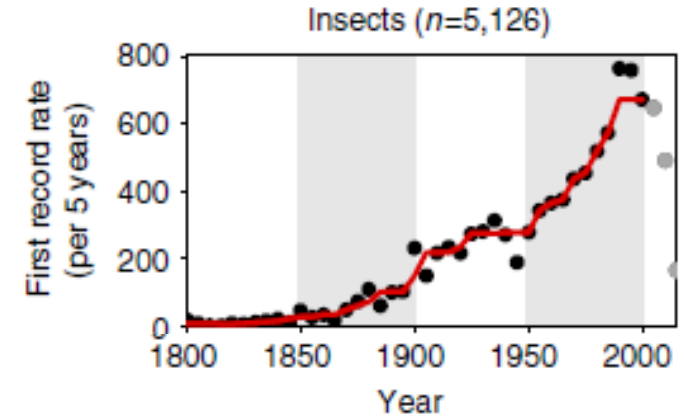
Protezione delle colture

- Ogni anno, **fino al 40%** della **produzione agricola** mondiale viene **persa a causa di parassiti e malattie** delle piante (FAO)
- **Perdite** esacerbate da
 - **cambiamento climatico**
 - negli ultimi 30 anni perdite per 123 miliardi \$ all'anno a causa di **eventi calamitosi**



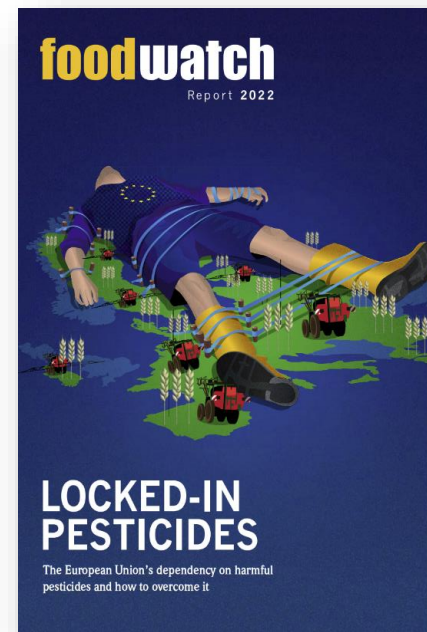
Protezione delle colture

- Specie invasive
 - Costituiscono una **sfida economica** ed **ecologica** globale perché possono alterare **comunità** e **servizi ecosistemici**

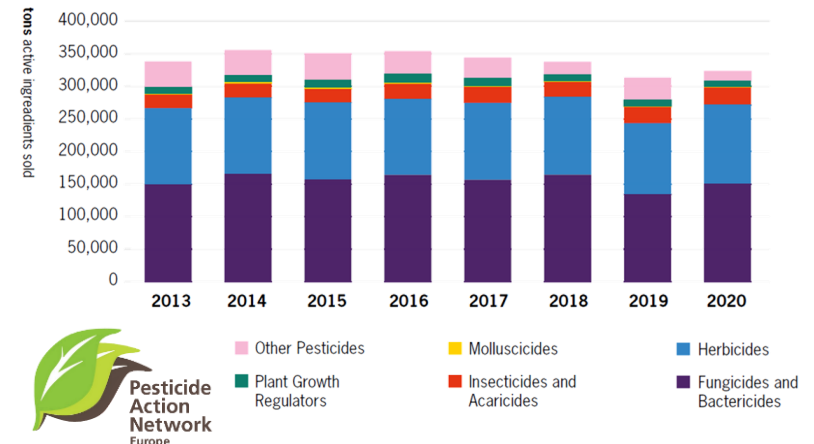


Protezione delle colture

- Le perdite di produzione sono ancora principalmente contenute attraverso l'**uso di prodotti fitosanitari**

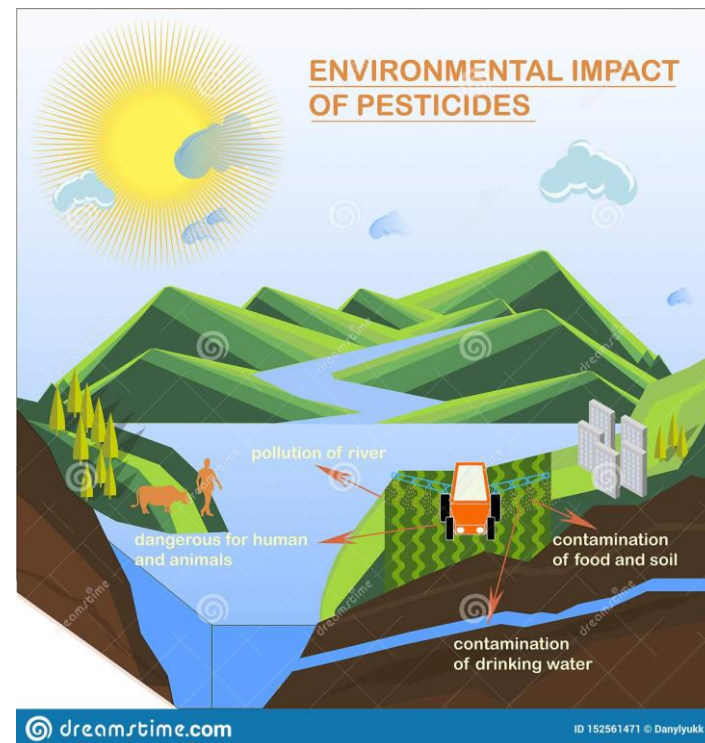


PESTICIDE SALES (KG ACTIVE INGREDIENTS) IN THE EU-27 2013-2020



Protezione delle colture

- Effetti secondari dei prodotti fitosanitari
 - **Residui** alimenti
 - **Tossicità** per gli operatori
 - **Resistenza** parassiti
 - Effetti negativi organismi utili
 - **Contaminazione** ambientale
 - Riduzione **biodiversità**



Esigenze attuali e future della difesa

- **Domanda alimentare**
- **Ambiente sicuro**
- **Ridurre i pesticidi**
- **Mitigare il cambiamento climatico**

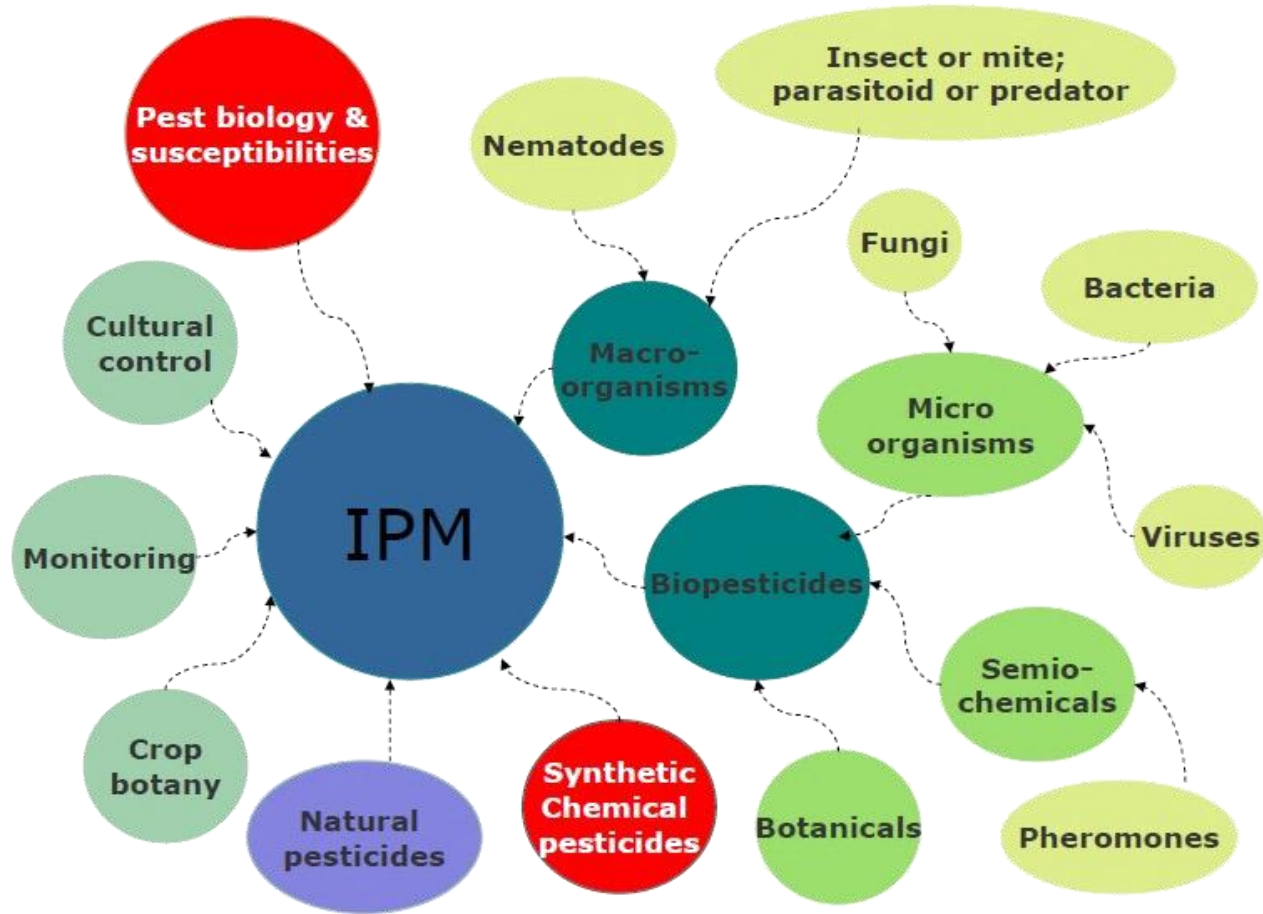


La difesa delle piante in EU

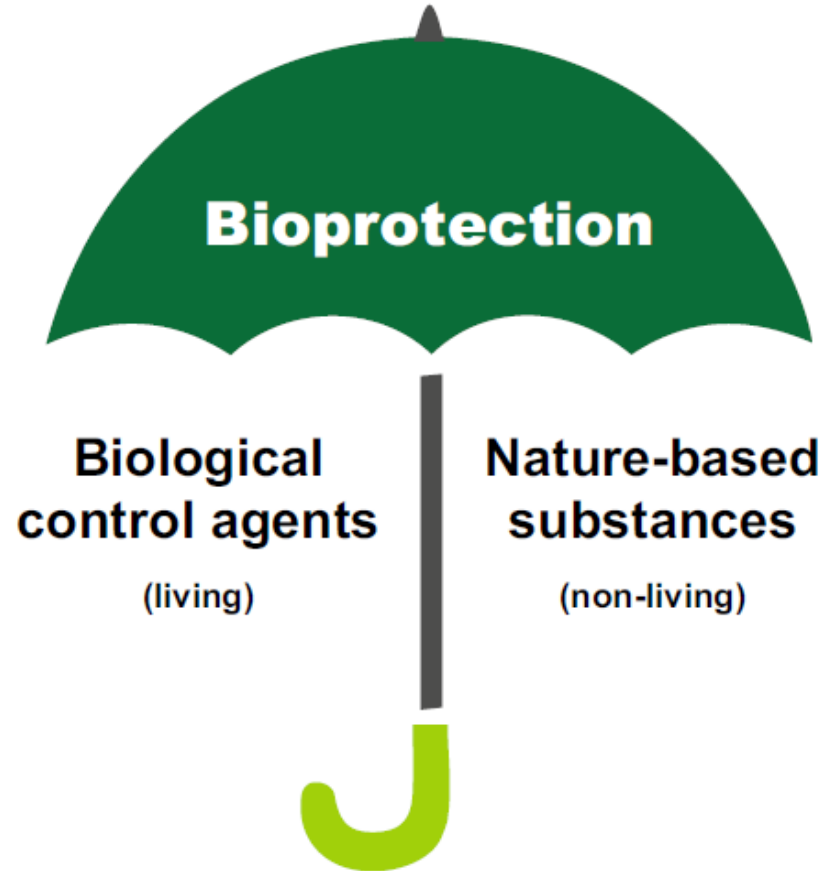
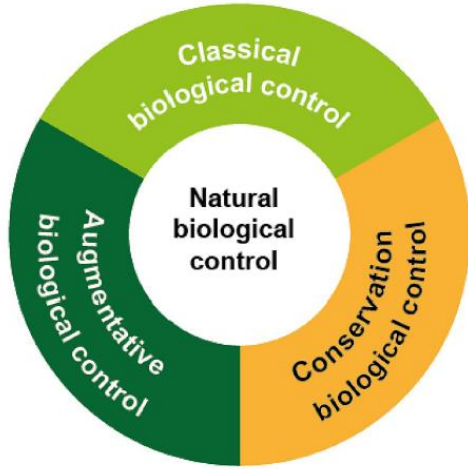
- **Uso sostenibile dei pesticidi**
(Direttiva 2009/128/CE)
 - Riduzione principi attivi pericolosi
- **Sicurezza alimentare e protezione biodiversità**
(from Farm to Fork and Biodiversity strategies)
 - Ridurre del 50% l'uso dei pesticidi chimici entro il 2030
 - Miglioramento alternative ecosostenibili



Difesa integrata



Bioprotezione



Prodotti fitosanitari di origine naturale

- Sostanze di origine naturale (biopesticides)
 - **Microrganismi** (virus, batteri, funghi) e/o prodotti da essi derivati
 - **Sostanze di origine vegetale** (botanicals)
 - Nematodi entomopatogeni
 - Feromoni
 - Geni impiegati per ottenere piante geneticamente modificate resistenti o tolleranti a fitofagi e patogeni (OGM)

(Copping & Menn, 2000)

Agenti di controllo biologico

➤ Uso di **antagonisti naturali**

- Artropodi entomofagi
 - Predatori
 - Parassitoidi
- Nematodi entomopatogeni
- Microorganismi



Controllo biologico classico

➤ Cambio di paradigma

Era dei benefici

- Molte introduzioni
- Studi sui benefici
- Modelli di valutazione di efficacia

1888

1990s

Controllo biologico classico

➤ Cambio di paradigma

Era dei benefici

- Molte introduzioni
- Studi sui benefici
- Modelli di valutazione di efficacia

↑
1888

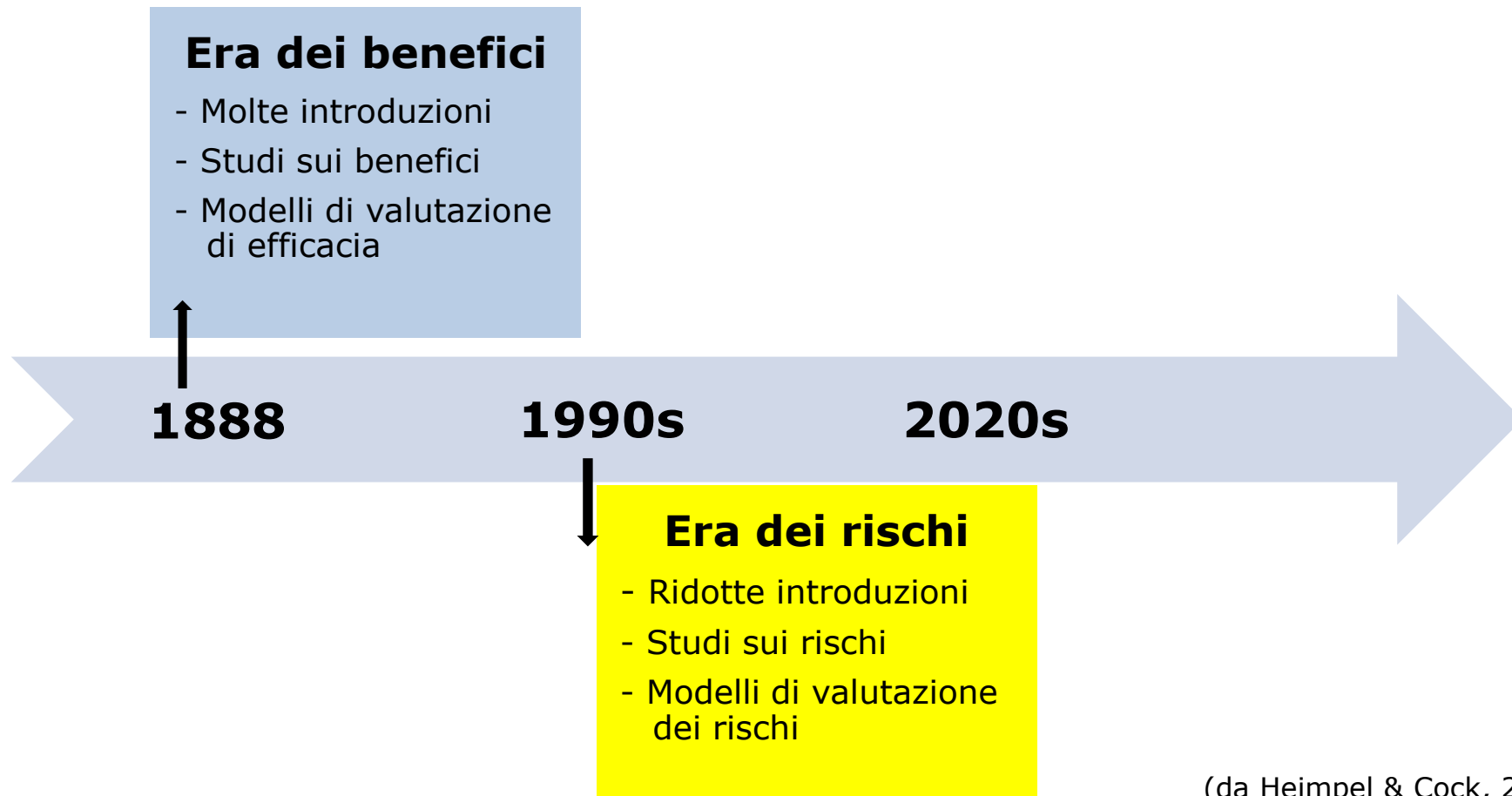
1990s



(da Heimpel & Cock, 2018 modif.)

Controllo biologico classico

➤ Cambio di paradigma



(da Heimpel & Cock, 2018 modif.)

Controllo biologico classico

➤ Cambio di paradigma

Era dei benefici

- Molte introduzioni
- Studi sui benefici
- Modelli di valutazione di efficacia

1888

1990s

2020s

Era dei rischi

- Ridotte introduzioni
- Studi sui rischi
- Modelli di valutazione dei rischi

DOI: 10.1111/app.12801

SAFE USE OF BIOLOGICAL CONTROL

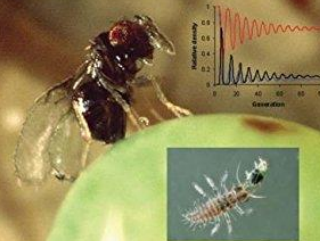
PM 6/3 (5) Biological control agents safely used in the EPPO region

Ann. Rev. Entomol. 2006. 51:609-34
doi: 10.1146/annurev.ento.51.110104.151129
Copyright © 2006 by Annual Reviews. All rights reserved
First published online as a Review in Advance on September 7, 2005

ASSESSING RISKS OF RELEASING EXOTIC
BIOLOGICAL CONTROL AGENTS
OF ARTHROPOD PESTS

J.C. van Lenteren,¹ J. Bale,² F. Bigler,³ H.M.T. Hokkanen,⁴
and A.J.M. Loomans⁵

ENVIRONMENTAL IMPACT
OF INVERTEBRATES FOR
BIOLOGICAL CONTROL
OF ARTHROPODS
METHODS AND RISK ASSESSMENT



Edited by
Bigler, D. Babendreier and U. Kuhlmann

CABI Publishing

Evaluating
Indirect
Ecological
Effects of
Biological
Control



Edited by
E. Wajnberg,
J.K. Scott and
P.C. Quimby

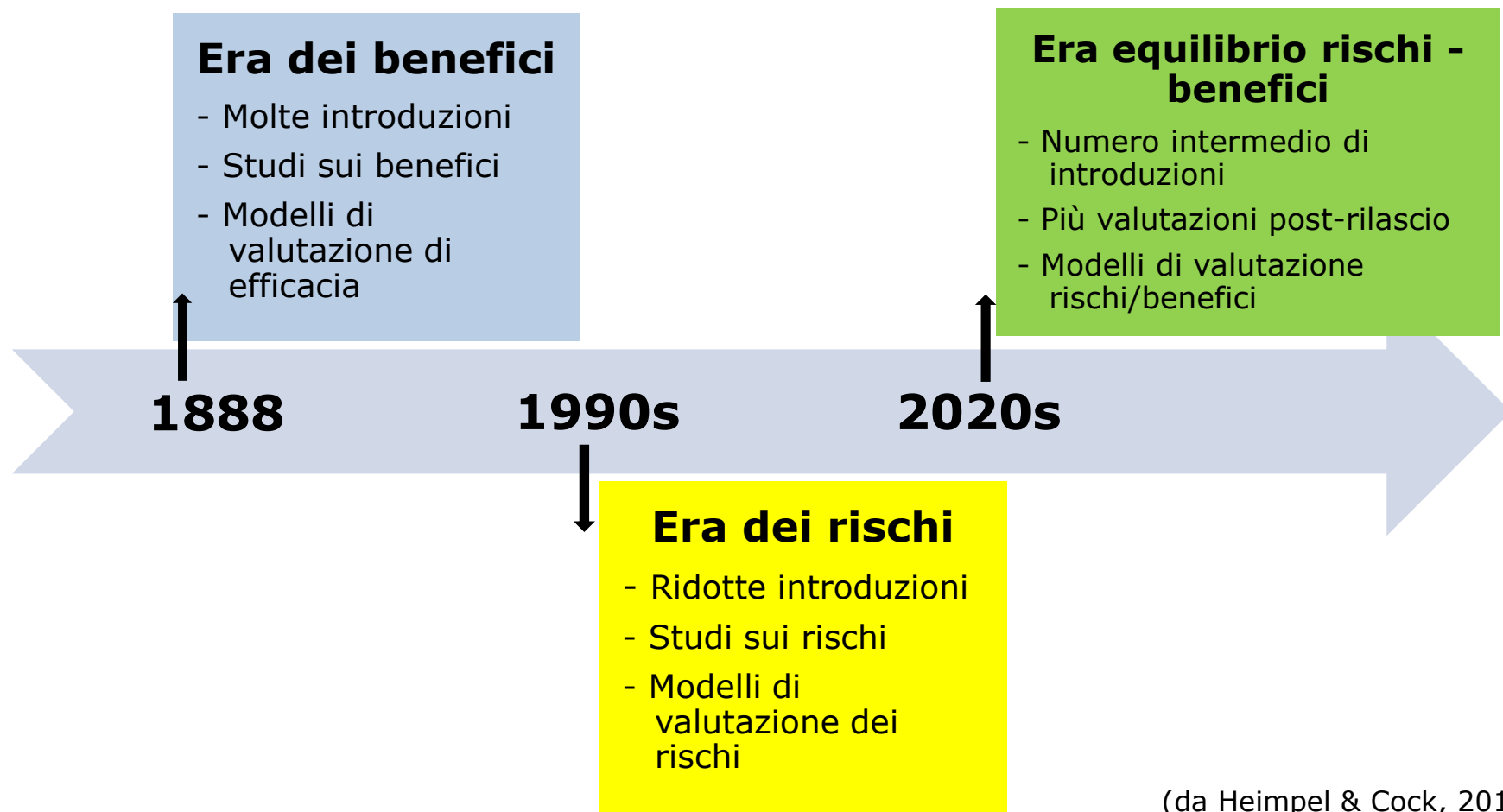


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(da Heimpel & Cock, 2018 modif.)

Controllo biologico classico

➤ Cambio di paradigma



Controllo biologico classico

➤ Cambio di paradigma

Received: 25 August 2023 | Revised: 24 February 2024 | Accepted: 22 April 2024

DOI: 10.1002/eap.3012

ARTICLE

ECOLOGICAL
APPLICATIONS
Evolutionary Biology & Control

A benefit-risk analysis for biological control introductions based on the protection of native biodiversity

George E. Heimpel¹ | Paul K. Abram² | Charlotte E. Causton³ |
Sabrina L. Celis¹ | Moshe Coll⁴ | Ian C. W. Hardy⁵ | Marc Mangel⁶ |
Nicholas J. Mills⁷ | Michal Segoli⁸

2020s

Era equilibrio rischi - benefici

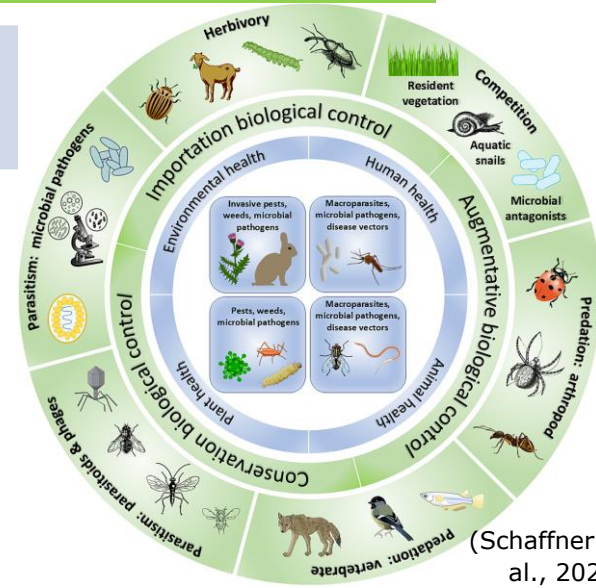
- Numero intermedio di introduzioni
- Più valutazioni post-rilascio
- Modelli di valutazione rischi/benefici



BioControl (2023) 68:1–12
<https://doi.org/10.1007/s10526-022-10174-2>

First report on classical biological control releases of the larval parasitoid *Ganaspis brasiliensis* against *Drosophila suzukii* in northern Italy

Lorenzo Fellin · Alberto Grassi · Simone Puppato ·
Alberto Saddi · Gianfranco Anfora ·
Claudio Ioratti · Marco Valerio Rossi-Stacconi



(Schaffner et al., 2024)

Controllo biologico aumentativo

➤ Ausiliari allevati in biofabbriche

- Più di 170 specie riportate
(van Lenteren et al., 2012)
- ~25 le specie più utilizzate

Table 2 The most important invertebrate biological control agents used in augmentative biological control ranked by number of countries in which each is used (modified after Cock et al. 2010)

Biological control agent	Family	Target(s)	No. of countries where used	Year of first use
1. <i>Amblyseius swirskii</i>	Phytoseiidae	Whiteflies, thrips, mites	>20	2005
2. <i>Aphidius colemani</i>	Braconidae	Aphids	>20	1991
3. <i>Aphidoletes aphidimyza</i>	Cecidomyiidae	Aphids	>20	1989
4. <i>Dacnusa sibirica</i>	Braconidae	Leafminers	>20	1981
5. <i>Diglyphus isaea</i>	Eulophidae	Leafminers	>20	1984
6. <i>Encarsia formosa</i>	Aphelinidae	Whiteflies	>20	1926
7. <i>Macrolophus pygmaeus</i> (=nubilis)	Miridae	Whiteflies	>20	1994
8. <i>Neoseiulus cucumeris</i> (=Amblyseius cucumeris)	Phytoseiidae	Thrips	>20	1985
9. <i>Phytoseiulus persimilis</i>	Phytoseiidae	Mites	>20	1968
10. <i>Steinernema feltiae</i>	Steinernematidae	Sciarids	>15	1984
11. <i>Aphidius ervi</i>	Braconidae	Aphids	>15	1996
12. <i>Orius laevigatus</i>	Anthoridae	Thrips	>15	1993
13. <i>Cryptolaemus montrouzieri</i>	Coccinellidae	Coccids, pseudococcids	>15	1989
14. <i>Galeolaelaps aculeifer</i> (=Hypoaspis aculeifer)	Laelapidae	Sciarids	>15	1996
15. <i>Feltiella acarisuga</i> (=Therodiplosis persicae)	Cecidomyiidae	Mites	>15	1990
16. <i>Leptomastix dactylopii</i>	Encyrtidae	Pseudococcids	>15	1984
17. <i>Stratiolaelaps miles</i> (=Hypoaspis miles)	Laelapidae	Sciarids	>15	1995
18. <i>Aphelinus abdominalis</i>	Aphelinidae	Aphids	>10	1992
19. <i>Heterorhabditis bacteriophora</i>	Heterorhabditidae	Coleopterans	>10	1984
20. <i>Heterorhabditis megidis</i>	Heterorhabditidae	Coleopterans	>10	1990
21. <i>Neoseiulus californicus</i> (=Amblyseius californicus)	Phytoseiidae	Mites, thrips	>10	1985
22. <i>Eretmocerus eremicus</i>	Aphelinidae	Whiteflies	>10	1995
23. <i>Eretmocerus mundus</i>	Aphelinidae	Whiteflies	>10	2001
24. <i>Episyrphus balteatus</i>	Syrphidae	Aphids	>10	1990
25. <i>Trichogramma evanescens</i>	Trichogrammatidae	Lepidopterans	>10	1975

Controllo biologico aumentativo

➤ Fonti alimentari aggiuntive

- Prede
- Derivate da insetti fitomizi
- Derivate dalle piante



Feeding supplements

Artemac™ > Nutrimac™ & Nutrimac-Plus™ >
Biogluc® > Nutrimite™ >
Biosweet >



Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in
Insect Science

Editorial overview: Parasites/parasitoids/biological control (2024) — research advances on plant-derived food sources in biological control

Pablo Urbaneja-Bernat, Alejandro Tena and Cesar Rodriguez-Saona



Received: 10 October 2023 | Accepted: 24 May 2024

DOI: 10.1111/1365-2435.14605

RESEARCH ARTICLE

Functional Ecology



Not just candy: A herbivore-induced defence-related plant protein in honeydew enhances natural enemy fitness

Pablo Urbaneja-Bernat¹ | Cesar Rodriguez-Saona² | M. Luz Valero³ |
Joel González-Cabrera⁴ | Alejandro Tena⁵

BioControl (2024) 69:575–588
<https://doi.org/10.1007/s10526-023-10237-y>



The indirect effect of nectar-inhabiting yeasts on olfactory responses and longevity of two stink bug egg parasitoids

Jay Darryl L. Ermio¹ · Ezio Peri² · Patrizia Bella³ · Michael Rostás⁴ ·
Islam S. Sobhy⁵ · Tom Wenseleers⁶ · Stefano Colazza⁷ · Bart Llevens⁸ ·
Antonino Cusumano⁹

Controllo biologico aumentativo



- Selezione di ceppi di entomofagi
- Modelli di simulazione dei rilasci
- Rilasci meccanizzati



Biological control of spider mites in North-Italian vineyards using pesticide resistant predatory mites

Mauro Lorenzon^a, Alberto Pozzebon^a, Carlo Duso^a

^a Department of Agronomy, Food, Natural Resources, Animals and Environment – University of Padova, viale dell'Università, 16 35020 Legnaro (PD), Italy.

Biological Control 188 (2024) 105413



Contents lists available at ScienceDirect

Biological Control

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



Enhancing the biocontrol potential of the predator *Nesidiocoris tenuis* through genetic selection

Meritxell Pérez-Hedo, Raül Ortells-Fabra, Miquel Alonso-Valiente, Omar Ruíz-Rivero, Alberto Urbaneja

scientific reports

Check for updates

OPEN Optimizing the releasing strategy used for the biological control of the sugarcane borer *Diatraea saccharalis* by *Trichogramma galloi* with computer modeling and simulation

Adriano Gomes Garcia^{1,2}, Eric Wajnberg^{1,2,3} & José Roberto Postali Parra¹

Rilasci meccanizzati



Habitat management

- **piante compagne e piante banca** per incrementare la **biodiversità** e favorire il **controllo biologico aumentativo e conservativo**



Microrganismi entomopatogeni

Principio attivo	microrganismo	attività	formulati registrati
<i>Adoxophyes orana</i> GV	GranuloVirus	insetticida	1
<i>Bacillus thuringiensis</i> (Kurstaki, Aizawai, Tenebrionis)	Batterio	insetticida	25
<i>Bacillus firmus</i>	Batterio	nematocida	1
<i>Beauveria bassiana</i>	Fungo	insetticida	4
<i>Cydia pomonella</i> GV*	GranuloVirus	insetticida	7 (+1)
<i>Lecanicillium muscarium</i>	Fungo	insetticida	1
<i>Metarhizium anisopliae</i>	Fungo	insetticida	2
<i>Helicoverpa armigera</i> NPV	Nucleopoliedrovirus	insetticida	1
<i>Paecilomyces fumosoroseus</i>	Fungo	insetticida	1
<i>Paecilomyces lilacinus</i>	Fungo	nematocida	1
<i>Spodoptera littoralis</i> NPV	Nucleopoliedrovirus	insetticida	1

(dati al 2019)

Microrganismi entomopatogeni

➤ Novità regolatoria

1.9.2022

EN

Official Journal of the European Union

L 227/2

COMMISSION REGULATION (EU) 2022/1438

of 31 August 2022

amending Annex II to Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards specific criteria for the approval of active substances that are micro-organisms

(Text with EEA relevance)

Journal of Invertebrate Pathology 126 (2015) 71–77



ELSEVIER

Contents lists available at ScienceDirect

Journal of Invertebrate Pathology

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



Pathogenicity and characterization of a novel *Bacillus cereus sensu lato* isolate toxic to the Mediterranean fruit fly *Ceratitis capitata* Wied.

Luca Ruiu*, Giovanni Falchi, Ignazio Floris, Maria Giovanna Marche, Maria Elena Mura, Alberto Satta



AMERICAN
SOCIETY FOR
MICROBIOLOGY

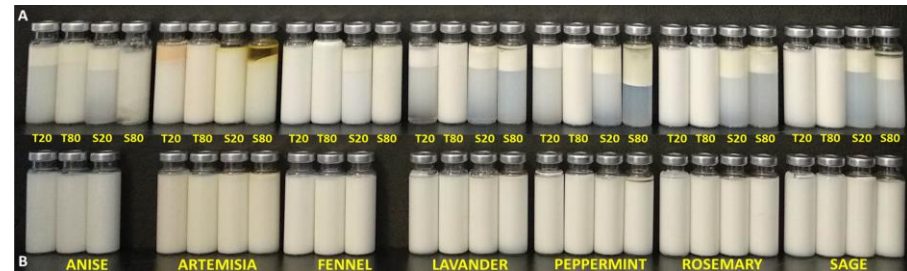
genomeATMnnouncements

Genome Sequence of *Brevibacillus laterosporus* UNISS 18, a Pathogen of Mosquitoes and Flies

Salvatore Camiolo, Andrea Porceddu, Luca Rulu
Dipartimento di Agraria, University of Sassari, Sassari, Italy

Sostanze di origine naturale

- sostanze prodotte da microrganismi
 - spinosine
 - avermectine
- vegetali (estratti, oli essenziali)
 - **aglio, agrumi**, anice, artemisia, finocchio, lavanda, menta piperita, rosmarino, salvia, citronella
 - azadiractina
 - piretrine



Sostanze di origine naturale

- vegetali (estratti, olii essenziali)
 - **aglio, agrumi**, anice, artemisia, finocchio, lavanda, menta piperita, rosmarino, salvia, citronella

Journal of Pest Science
https://doi.org/10.1007/s10340-024-01800-2

ORIGINAL PAPER



High-energy emulsification of *Allium sativum* essential oil boosts insecticidal activity against *Planococcus citri* with no risk to honeybees

Antonino Modafferi¹ · Giulia Giunti² · Alberto Urbaneja³ · Francesca Laudani¹ · Ilaria Latella¹ · Meritxell Pérez-Hedo³ · Michele Ricupero⁴ · Vincenzo Palmeri¹ · Orlando Campolo¹



Entomologia Generalis, Volume 43 (2023), Issue 5, 1001–1010
Published online October 5, 2023

Open Access Article



Garlic and peppermint essential oils elicit plant defensive responses in sweet peppers

Michele Ricupero^{1,2}, Antonio Biondi¹, Orlando Campolo³, Miquel Alonso-Valiente², Carolina Gallego², Lucia Zappalà¹, Alberto Urbaneja², and Meritxell Pérez-Hedo^{2,*}

Sostanze di origine naturale

- **Estratti vegetali**
 - uso scarti lavorazione
 - Scarti di caffè; potatura verde vite
 - biodegradabili
 - ridotto impatto ambientale



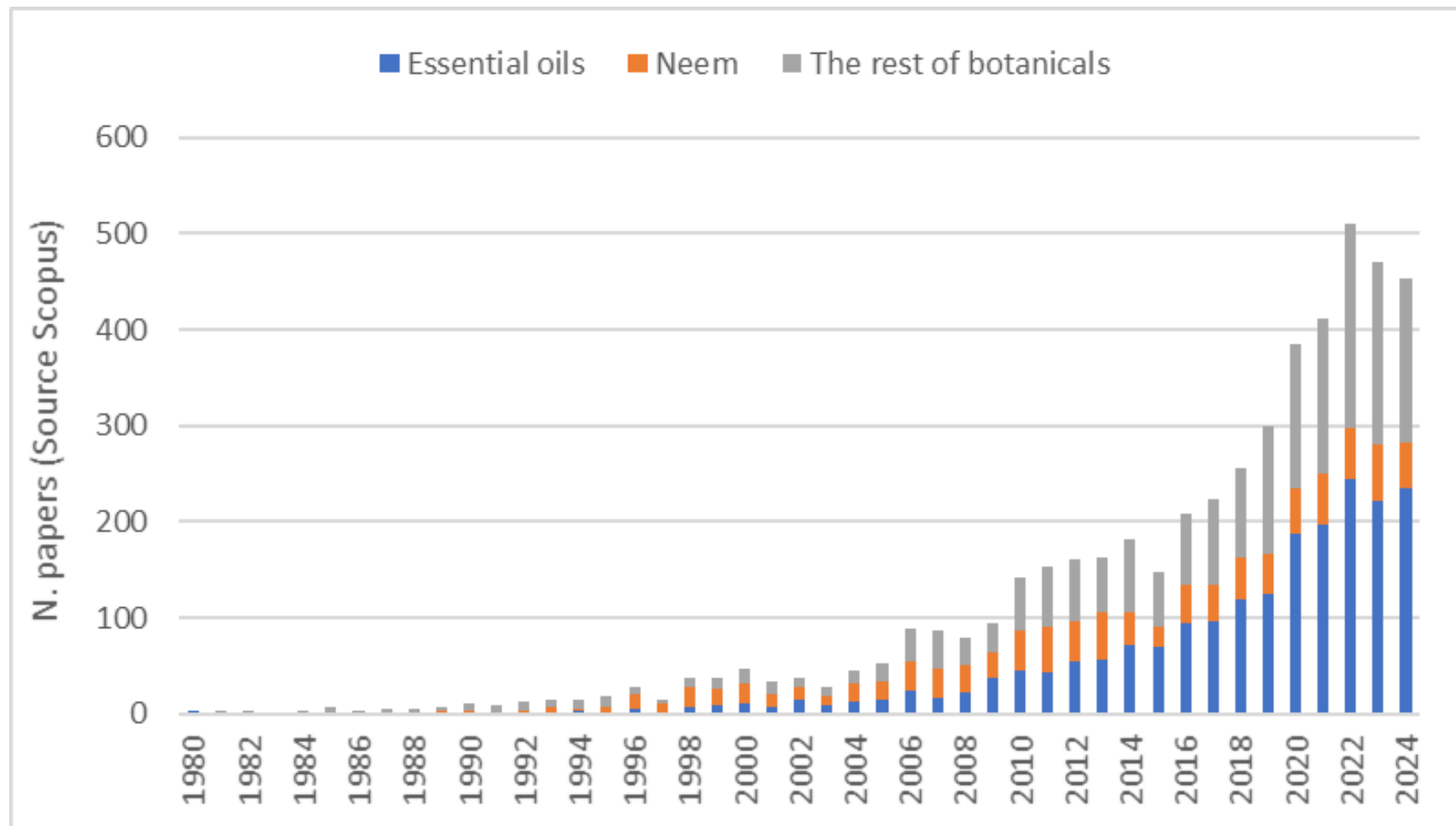
agritech



Università degli Studi di Torino



Publicazioni sui botanicals



Isaac Ishaaya · Subba Reddy Palli
A. Rami Horowitz *Editors*

Advanced Technologies for Managing Insect Pests

 Springer

Chapter 11 Plant Natural Products for Pest Management: The Magic of Mixtures

Yasmin Akhtar and Murray B. Isman

 **ANNUAL
REVIEWS**

Annual Review of Entomology
Botanical Insecticides
in the Twenty-First
Century—Fulfilling
Their Promise?

Murray B. Isman

Faculty of Land and Food Systems, University of British Columbia, Vancouver,
British Columbia V6T 1Z4, Canada; email: murray.isman@ubc.ca

Annu. Rev. Entomol. 2020. 65:11.1–11.17

Keywords

Essential Oils in Insect Control: Low-Risk Products in a High-Stakes World

Catherine Regnault-Roger,¹ Charles Vincent,^{2,*}
and John Thor Arnason³

¹UMR CNRS UPPA 3254 IPREM-EEM, Université de Pau et des Pays de l'Adour,
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³Faculty of Science, University of Ottawa, Ottawa, Ontario K1N 6N5, Canada;
email: John.Arnason@uOttawa.ca

Annu. Rev. Entomol. 2012. 57:405–24

Keywords



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Annu. Rev. Entomol. 2006. 51:45–66
doi: 10.1146/annurev.ento.51.110104.151146
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First published online as a Review in Advance on July 11, 2005

BOTANICAL INSECTICIDES, DETERRENTS, AND REPELLENTS IN MODERN AGRICULTURE AND AN INCREASINGLY REGULATED WORLD

Murray B. Isman

Faculty of Land and Food Systems, University of British Columbia,
Vancouver, British Columbia, V6T 1Z4, Canada; email: murray.isman@ubc.ca

Pest Management Science

Pest Manag Sci 64:8–11 (2008)

Perspective

Botanical insecticides: for richer, for poorer

Murray B Isman*

Faculty of Land and Food Systems, University of British Columbia, Vancouver V6T 1Z4, Canada

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Opinion

CellPress

Botanical insecticide research: many publications, limited useful data

Murray B. Isman¹ and Michael L. Grieneisen^{2,3}

¹Faculty of Land and Food Systems, University of British Columbia, Vancouver, BC V6T1Z4, Canada

²AGIS Lab, Department of Land, Air and Water Resources, University of California, Davis, CA 95616, USA

³Wenzhou Medical University, Wenzhou, Zhejiang 325035, China

Review

Toxics or Lures? Biological and Behavioral Effects of Plant Essential Oils on Tephritidae Fruit Flies

Valeria Zeni¹, Giovanni Benelli^{1,*}, Orlando Campolo², Giulia Giunti², Vincenzo Palmeri², Filippo Maggi³, Roberto Rizzo⁴, Gabriella Lo Verde⁵, Andrea Lucchi¹ and Angelo Canale¹

SCIENTIFIC REPORTS

Correction: Author Correction

OPEN

Citrus peel essential oil nanoformulations to control the tomato borer, *Tuta absoluta*: chemical properties and biological activity

Received: 7 July 2017
Accepted: 21 September 2017
Published online: 12 October 2017

Orlando Campolo¹, Asma Cherif^{2,3}, Michele Ricupero², Gaetano Siscaro², Kaouthar Grissa-Lebdi², Agatino Russo², Lorena M. Cucci⁴, Patrizia Di Pietro⁴, Cristina Satriano⁴, Nicolas Desneux⁴, Antonio Biondi², Lucia Zappalà² & Vincenzo Palmeri¹

Hindawi
Journal of Food Quality
Volume 2018, Article ID 6906105, 18 pages
<https://doi.org/10.1155/2018/6906105>

WILEY



Review Article

Essential Oils in Stored Product Insect Pest Control

Orlando Campolo¹,¹ Giulia Giunti²,¹ Agatino Russo²,² Vincenzo Palmeri,¹ and Lucia Zappalà²



Contents lists available at ScienceDirect

Biological Control

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



Non-target effects of essential oil-based biopesticides for crop protection: Impact on natural enemies, pollinators, and soil invertebrates

Giulia Giunti^a, Giovanni Benelli^{b,*}, Vincenzo Palmeri^c, Francesca Laudani^c, Michele Ricupero^d, Renato Ricciardi^b, Filippo Maggi^e, Andrea Lucchi^b, Raul Narciso C. Guedes^f, Nicolas Desneux^g, Orlando Campolo^c



Available online at www.sciencedirect.com

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Current Opinion in

Environmental Science & Health

Ecological costs of botanical nano-insecticides

Antonino Modafferi¹, Giulia Giunti², Giovanni Benelli³ and Orlando Campolo¹

Journal of Pest Science
<https://doi.org/10.1007/s10340-024-01800-2>

ORIGINAL PAPER



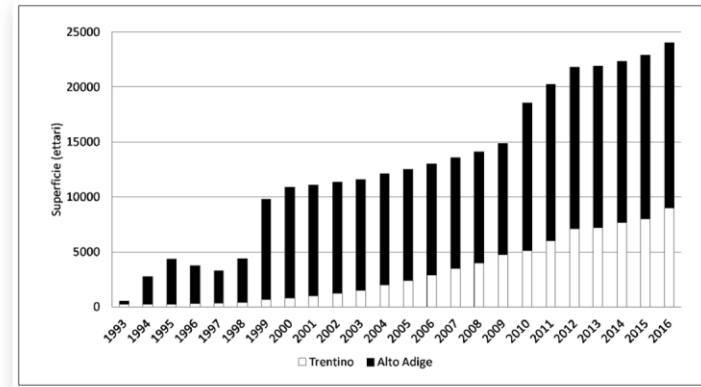
High-energy emulsification of *Allium sativum* essential oil boosts insecticidal activity against *Planococcus citri* with no risk to honeybees

Antonino Modafferi¹ · Giulia Giunti² · Alberto Urbaneja³ · Francesca Laudani¹ · Ilaria Latella¹ · Meritxell Pérez-Hedo³ · Michele Ricupero⁴ · Vincenzo Palmeri¹ · Orlando Campolo¹

Altri strumenti

- Feromoni
(confusione/disorientamento/catture)
 - Applicazioni di dispenser multi-target
 - Sostituzione dei diffusori ad emissione passiva con quelli a diffusione attiva tramite aerosol
 - Maggiore efficacia e costi ridotti

- Meleto
 - Confusione sessuale



(Ioriatti & Anfora, 2017)



Article

Sex Pheromone Aerosol Emitters for *Lobesia botrana* Mating Disruption in Italian Vineyards

Giovanni Benelli ¹, Renato Ricciardi ^{1,*}, Francesca Cosci ¹, Andrea Iodice ², Edith Ladumer ², Francesco Savino ² and Andrea Lucchi ¹

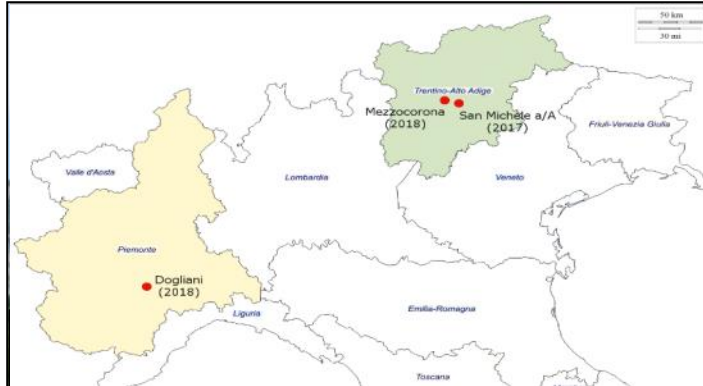
Altri strumenti

- Confusione a mezzo di diffusori vibrazionali
 - Emissione in Playback del segnale di Disturbo:
 - Interferenza sulle frequenze specifiche di comunicazione di *Scaphoideus titanus*



Altri strumenti

- Confusione a mezzo di diffusori vibrazionali
 - Vigneti vibrazionali



Pannelli Solari



Prospettive

- Incremento delle difese della pianta
 - PGPF (Plant Growth Promoting Fungi) del genere *Trichoderma*
 - Noti come agenti di lotta biologica a patogeni
 - Accertato il loro effetto positivo sia sulle difese della pianta che sulla crescita
 - Aumentata produzione di sostanze volatili che richiamano i nemici naturali
 - Funghi entomopatogeni endofiti (eg *Beauveria bassiana*, *Metarhizium anisopliae*)
- Biostimolanti, elicitori, corroboranti
- ...



Insect Science (2017) 00, 1–9, DOI 10.1111/1744-7917.12475

ORIGINAL ARTICLE

Trichoderma harzianum enhances tomato indirect defense against aphids

Mariangela Coppola^{1,*}, Pasquale Cascone^{2,*}, Maria Luisa Chiusano¹, Chiara Colantuono¹, Matteo Lorito¹, Francesco Pennacchio¹, Rosa Rao¹, Sheridan Lois Woo¹, Emilio Guerrieri²  and Maria Cristina Digilio¹ 

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RESEARCH ARTICLE

Functional Ecology 

Root inoculation with beneficial soil microbes enhances indirect plant defences induced by insect feeding and egg deposition

Tuğcan Alinç¹  | Ezio Peri¹  | Livio Torta¹  | Salvatore Guarino²  | Stefano Colazza¹  | Bart Lieveens^{3,4}  | Antonino Cusumano¹ 

Arthropod-Plant Interactions (2020) 14:289–300
<https://doi.org/10.1007/s11829-020-09746-9>

ORIGINAL PAPER

Check for updates 

Endophytic colonization by *Beauveria bassiana* increases the resistance of tomatoes against *Bemisia tabaci*

Qiu-Yang Wei¹ · Ya-Ying Li¹ · Chen Xu² · Yi-Xia Wu¹ · Ya-Ru Zhang¹ · Huai Liu¹





Review

Endophytic Entomopathogenic Fungi: A Valuable Biological Control Tool against Plant Pests

Spiridon Mantzoukas^{1,*} and Panagiotis A. Eliopoulos^{2,*} 

Prospettive

➤ Biopesticidi

– A base di microrganismi

- Utilizzo **sinergico** di **microrganismi** agenti di biocontrollo (i.e. *Trichoderma afroharzianum* e *Beauveria bassiana*), abbinati a bioinsetticidi registrati a base di *Bacillus thuringiensis* per il controllo di insetti nocivi

– RNAi

- Modalità di somministrazione
- Percorsi di registrazione

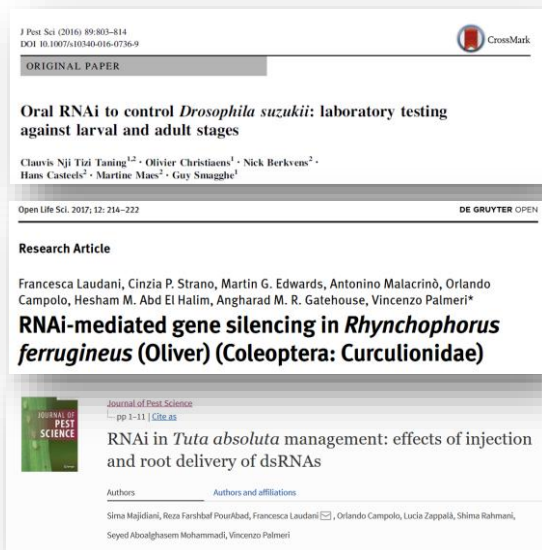
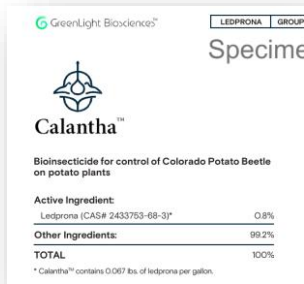


Table 1 Successful examples of RNAi-mediated gene knockdown in different insects

Target insect	Mode of delivery	Concentration of RNA	Target gene	Reference
<i>Anopheles gambiae</i>	Feeding nanoparticles	–	<i>AgCHSI</i> , <i>AgCHS2</i>	[142]
<i>Apis mellifera</i>	Abdominal injection	1 µl	Vitellogenin	[2]
<i>Apis mellifera</i>	Mixed with natural diet	0.5	Vitellogenin	[84]
<i>Apis mellifera</i>	Soaking	1.26	Toll-related receptor	[5]
<i>Diabrotica virgifera virgifera</i>	Artificial diet	5.4 ng/cm ²	Vacuolar ATPase subunit A	[11]
<i>Diabrotica virgifera virgifera</i>	Feeding	1,000 ng	DvSnf7	[19]
<i>Epiphyas postvittana</i>	Droplet feeding	1.0 µg	Gut carboxylase	[123]
<i>Glossina morsitans morsitans</i>	Blood meal	10 µg	Midgut protein TsetseEP	[127]
<i>Helicoverpa armigera</i>	Feeding	25–50 nM siRNA	Acetylcholine esterase	[64]
<i>Helicoverpa armigera</i>	Transgenic plant	–	Cytochrome P450 (CYP6AE1.4)	[69]
<i>Menduca sexta</i>	Injection	100 ng	Moricin	[33]
<i>Nilaparvata lugens</i>	Feeding	0.02, 0.1, and 0.5 mg/ml	Trehalose phosphate synthase (TPS)	[23]
<i>Phyllotreta striolata</i>	Injection	1 mg/ml	PsOr1	[143]
<i>Phyllotreta striolata</i>	Feeding	0.05–3.2 ng/ml	Arginine kinase	[144]
<i>Reticulitermes flavipes</i>	Artificial diet	13 µg	Cellulase	[145]
<i>Schistocerca gregaria</i>	Injection	5 µg dsRNA	Vitellogenin	[8]
<i>Schistocerca gregaria</i>	Injection	5 µg	gapdh	[134]
<i>Spodoptera frugiperda</i>	Droplet feeding	0.4 mg	Cytochrome P450 (CYP6BF1v4)	[38]
<i>Spodoptera litura</i>	Soaking and in artificial diet	–	Aminopeptidase N	[91]
<i>Spodoptera litura</i>	Injection	1.5 or 2.5 mg/ml	Vitellogenin receptor (VgR)	[99]
<i>Tribolium castaneum</i>	Injection	1 µg	eGFP	[78]

Prospettive

➤ **Controllo Simbiotico**

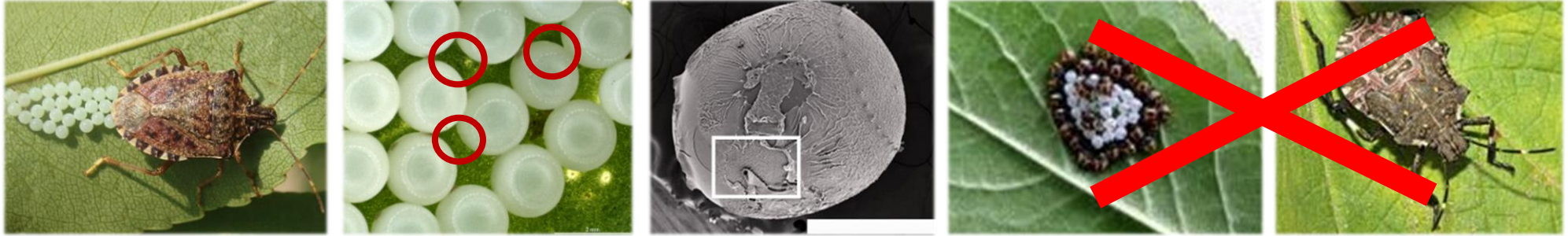
- Uso di simbionti microbici per veicolare sistemi di lotta a patogeni e insetti dannosi
- Controllo diretto dell'insetto: Sbilanciare la sex ratio o limitare la crescita delle popolazioni
- Controllo di patogeni trasmessi da insetti: Sviluppare meccanismi antagonisti per bloccare la trasmissione

Potenziali applicazioni di controllo simbiotico

- Lotta alla cimice asiatica *Halyomorpha halys* tramite l'eliminazione del batterio simbionte '*Candidatus Pantoea carbekii*'
 - *P. carbekii*, trasmessa verticalmente tramite secrezioni extra-chorion, è necessario allo sviluppo delle neanidi di *H. halys*



Potenziali applicazioni di controllo simbiotico



➤ Prodotti ad effetto accessorio battericida

➤ in laboratorio

- forte riduzione della sopravvivenza delle neanidi neonate

(Gonella et al., 2019)

➤ in laboratorio e campo

- confermata efficacia
- nessuna interferenza con i parassitoidi oofagi *Anastatus bifasciatus*, *Ooencyrtus telenomicida*, *Trissolcus kozlovi*

(Orrù et al., 2023)

Riflessioni

- Continue minacce da insetti esotici
 - *Bactrocera dorsalis*, *Diaphorina citri*, *Spodoptera frugiperda*...
- Rinnovata possibilità di attuare programmi di controllo biologico classico
- Necessità di ricerca e confronto su “strategie tabù” (paratransgenesi, RNAi, ...)
- Necessario lavoro su formulazione e registrazione di biopesticidi
- Necessaria formazione tecnici

Riflessioni

- Lezione dal passato per sfide future
 - *"A truly extraordinary variety of alternatives to the chemical control of insects is available. Some are already in use and have achieved brilliant success. Others are in the stage of laboratory testing. Still others are little more than ideas in the minds of imaginative scientists, waiting for the opportunity to put them to the test..."*

Rachel Carson (1962)





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