

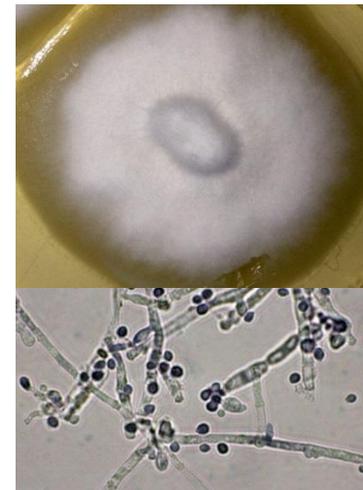
Scientific Insights in the Mode of Action of Microbial Control Agents (mBCAs)

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- mBCAs have been known for more than 100 years
- only a very limited number registered as PPPs
- those currently available on the market considered safe to humans and non-target organisms



Major drawbacks to extensive use:

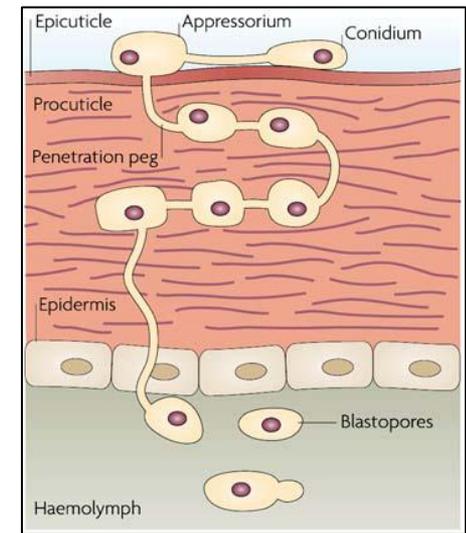
- **UV-sensitivity** - can be mitigated by using improved spraying and formulation technologies
- **speed of action** – no knock-down effect
- **inconsistency in efficacy** – may be at least in part due to:

**gaps in exploitation / knowledge
of mode of action?**

mBCAs – primary mode of action

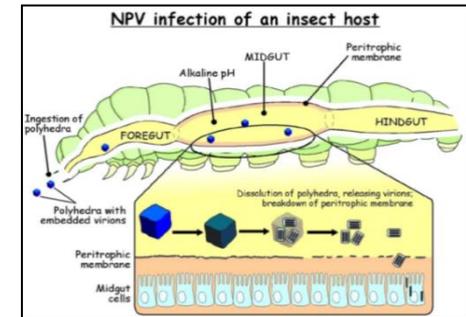
- **Entomopathogenic fungi - contact**

adherence of conidia to cuticle; spore germination; penetration inside host; vegetative growth in host's haemolymph; production of new conidia upon death of host.



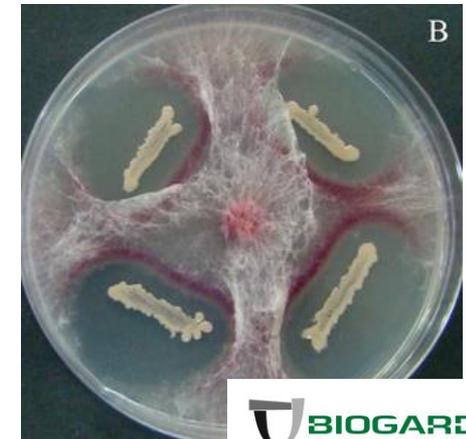
- **Baculoviruses - ingestion**

ingestion of Occlusion bodies (OBs); release of ODVs, which infect midgut cells; initiation of systemic infection; production of occluded virions; liquefaction of dead larva and release of progeny OBs.



- ***Bacillus subtilis* / *amyloliquefaciens* - multiple**

site exclusion, nutrient competition, disruption of pathogen growth, production of lipopeptides, induction of systemic resistance response in plants.

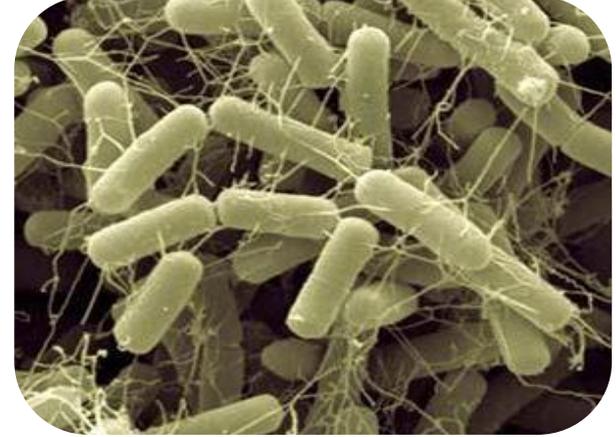


Matthew et al. 2007. Nature Reviews Microbiology 5: 377-383.

<http://www.microbiologybytes.com/virology/kalmakoff/baculo/baculo.html>.

Ongena & Jacuques, 2007. Trends in Microbiology 16(3). doi:10.1016/j.tim.2007.12.009

Is there more to it than this?



Maybe yes ...

1. Endophytic behavior of entomopathogenic fungi

2. Oviposition deterrent activity of entomopathogenic fungi

3. Manipulation of lepidopteran host behavior by baculoviruses

4. Vertical transmission of mBCAs

5. Optimization of *B. subtilis* / *amyloliquefaciens* activity

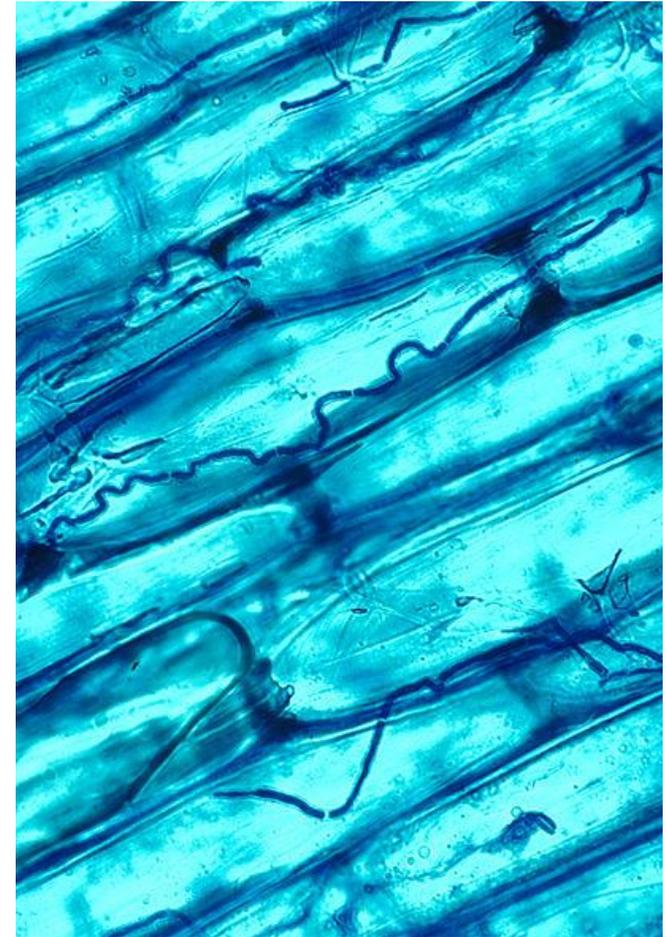
1. Endophytic behavior of entomopathogenic fungi

Endophytes (bacteria and fungi):

- have been found in all plant species studied to date
- can live within a plant for at least part of their life without causing disease.

Also some entomopathogenic *B. bassiana* strains can endophytically colonize several plant species.

- **systemic protection against damage by insects and / or plant pathogens?**



Neotyphodium coenophialum mycelia inhabiting the intercellular space of tall fescue leaf sheath tissue.

1. Endophytic behavior of entomopathogenic fungi

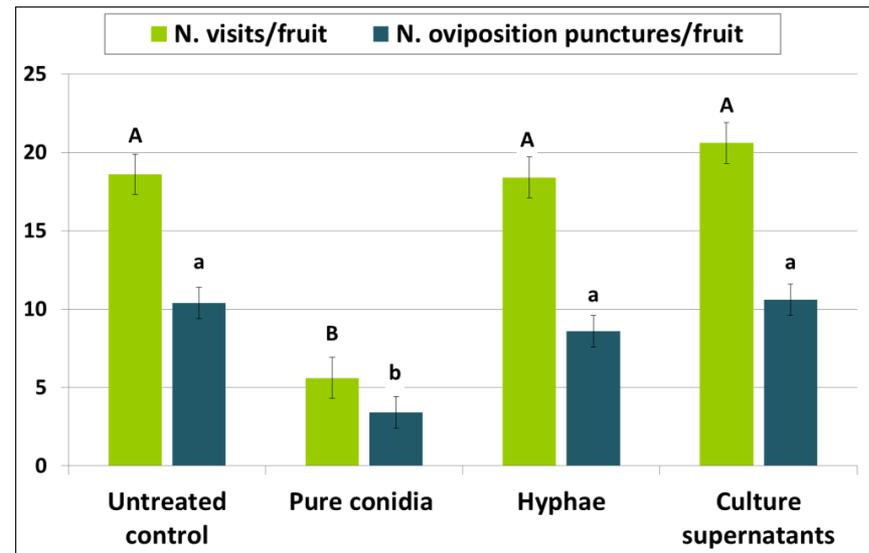
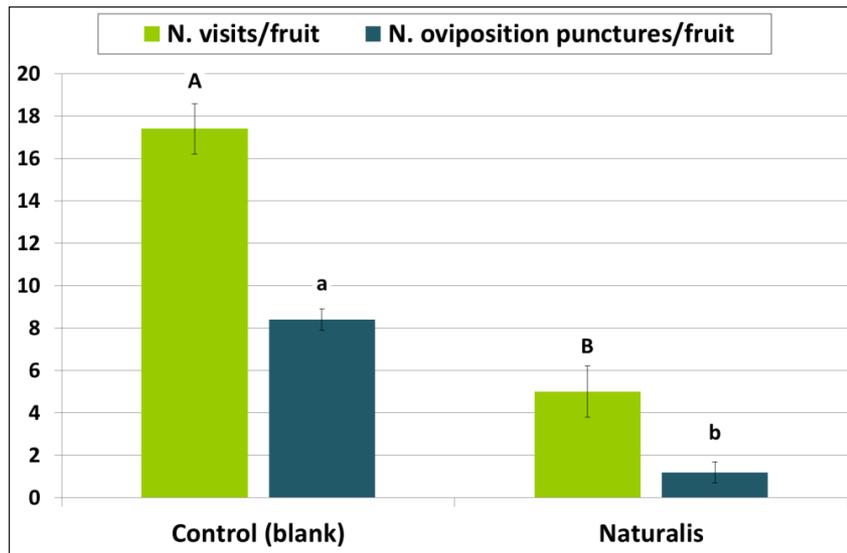
Rondot and Reineke, 2013.

- Endophytic establishment of the entomopathogen *Beauveria bassiana* in *Vitis vinifera* plants IOBC – WPRS Bulletin 90: 129.
- Potential of the entomopathogenic fungus *Beauveria bassiana* as an endophyte in grapevine *Vitis vinifera*. IOBC-WRPS meeting "Integrated Protection and Production in Viticulture" Ascona, 16th Oct. 2013.

http://www.iobc-wprs.org/pub/2013_WG_Viticulture_meeting_Ascona_CH/index.html

2. Oviposition deterrent activity of entomopathogenic fungi

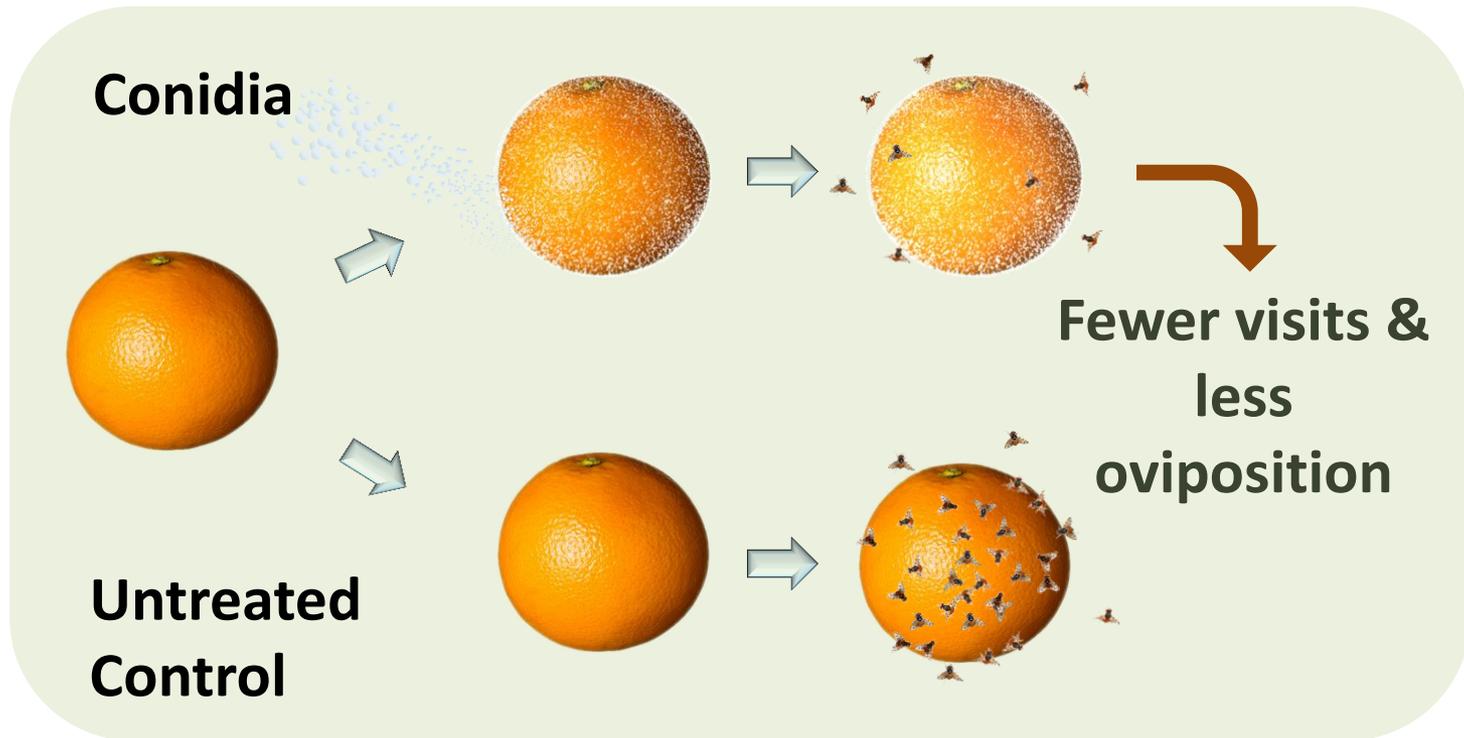
Effects of a commercially available, formulated *B. bassiana* strain, the blank formulation, and different fungal preparations on oviposition behaviour of Mediterranean fruit fly (*Ceratitis capitata*) in no-choice tests (Ruiu et al., 2013).



Oviposition deterrent effects exist for formulated product and pure conidia suspension, but not for blank formulation and other fungal fractions.

Intact conidia seem to be responsible for observed effects, because effects were observed immediately after application and lasted for 48 h.

2. Oviposition deterrent activity of entomopathogenic fungi



- Two hydrophobins, small proteins known to form a hydrophobic coating (rodlet layer), have been identified in the tested *B. bassiana* strain.
- The hydrophobic layer of conidia on the fruit surface may impair the ability of medflies to detect fruit-derived stimuli (odours, fruit humidity content), and be at least partially responsible for the oviposition deterrent activity.

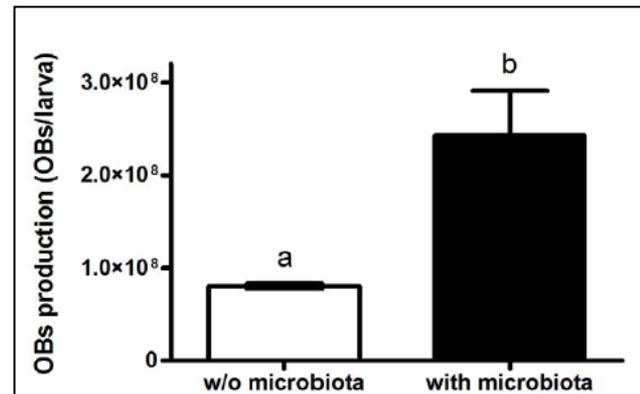
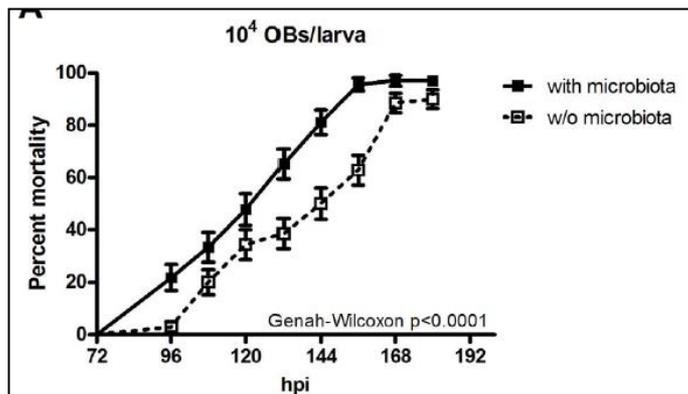
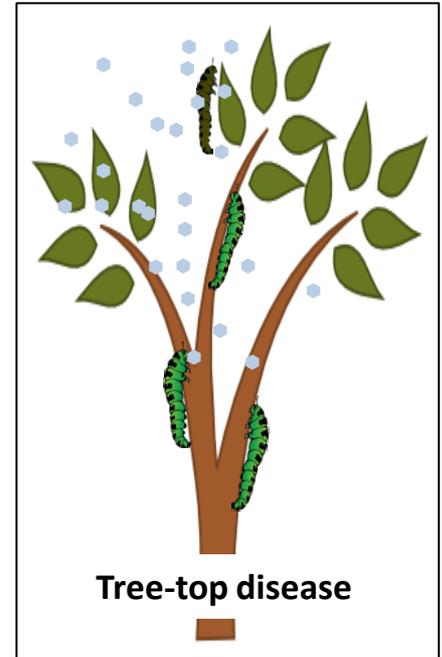
3. Manipulation of lepidopteran host behavior by baculoviruses

Baculoviruses contain an array of genes that alter the behavior of the host in order to enhance spread and infection.

e.g. gene (*ptp*) and enhanced locomotory activity in *Bombix mori* and *Spodoptera exigua*, gene (*egt*) and climbing behavior in *Lymantria dispar*.

Baculoviruses can also manipulate host-gene expression to enhance virulence and dispersion.

e.g. down-regulation of immune-related genes in the gut of SeMNPV-infected *Spodoptera exigua* larvae; significant increase in gut bacteria enhancing SePNPV pathogenicity, virulence, and dispersion.



Kamita et al., 2005. PNAS 102(7), 2584-2589.

Houte et al., 2012. PLOS ONE 7(10), e46933.

Hoover et al., 2011. *Science* 333, 1401.

Jakubowska et al., 2013. PLoS Pathog 9(5): e1003379.

4. Vertical transmission of mBCAs

Vertical transmission of endophytic *Beauveria bassiana* controlling poppy stem gall wasp in opium poppy (Quesada-Moraga et al., 2009, 2013)

- A *B. bassiana* strain that can become established endophytically in opium poppy plants was obtained from *Iraella luteipes* larvae. The strain was able to provide systemic protection against the pest.
- Plants obtained from seeds dressed with the fungus were endophytically colonized. The endophyte was detected in 50% of the seed samples formed in the new capsules.
- Colonized seeds were again sown, and the fungus was present in tissues and seeds of 19 out of the 24 plants obtained from the above mentioned seeds.

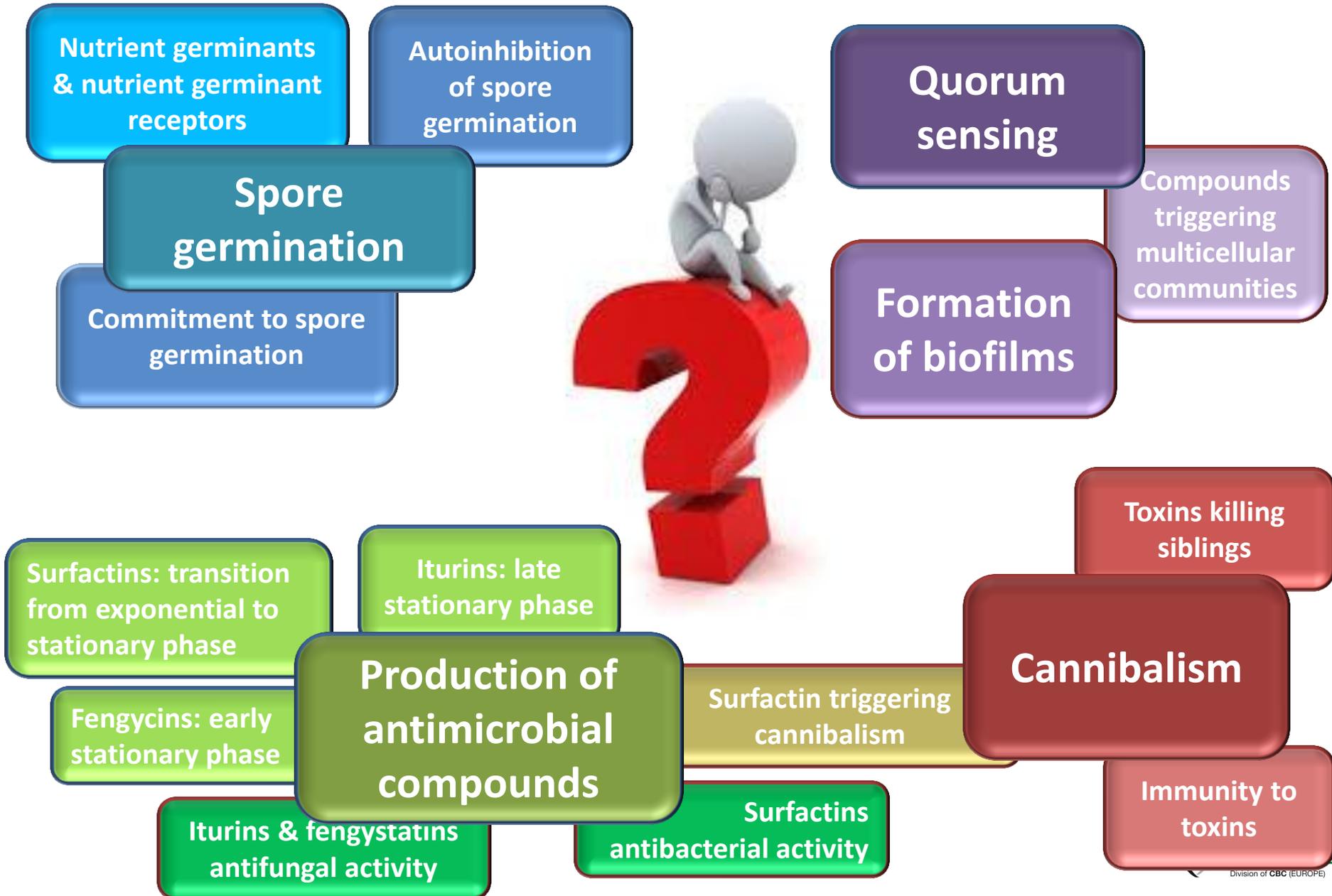
First report of vertical transmission in plants of an entomopathogenic endophytic fungus!

Quesada-Moraga et al., 2009. Environm. Entomol. 38(3): 723-730.

Quesada-Moraga et al., 2013. IOBC-WPRS Bulletin 90: 68.

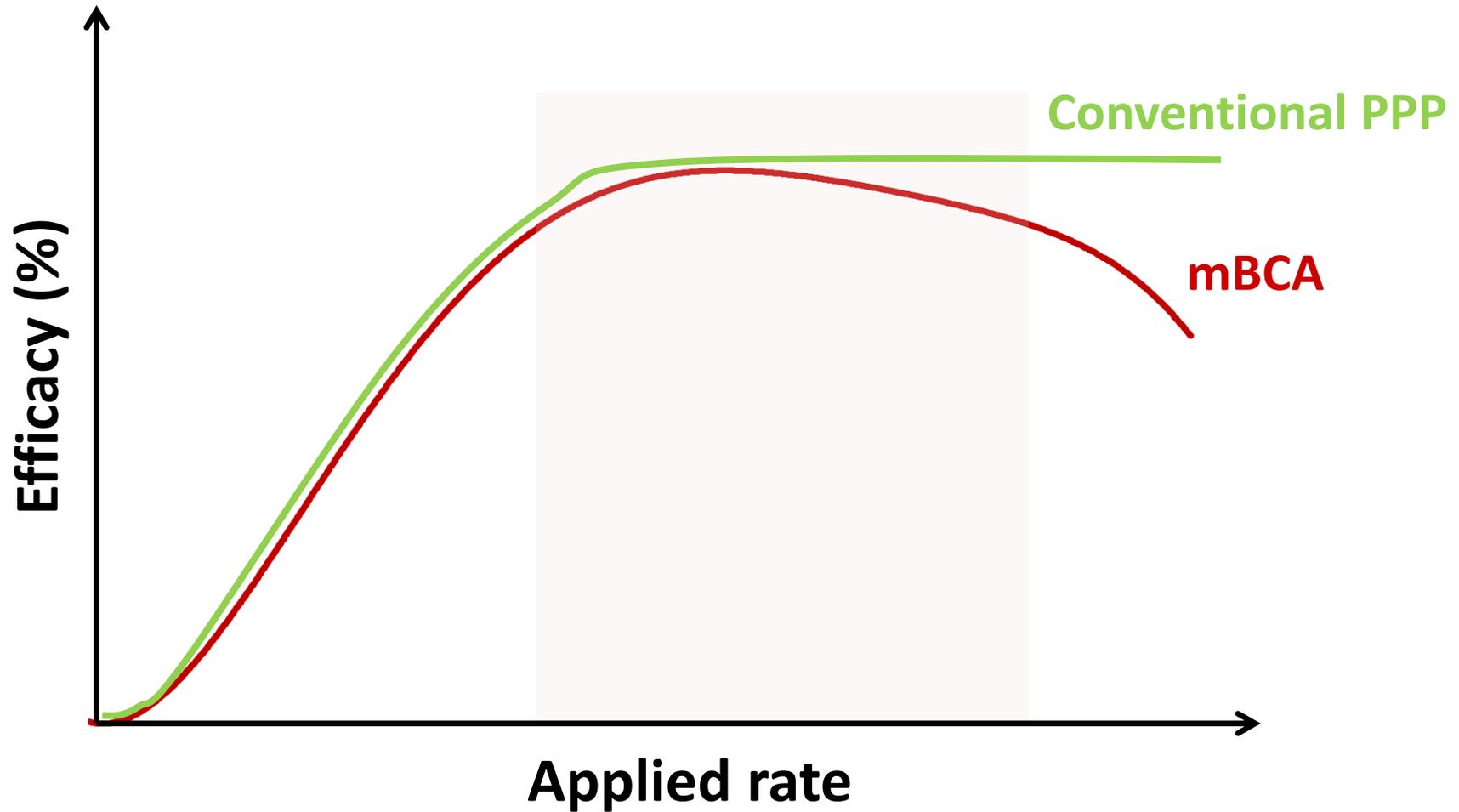


5. Optimization of *B. subtilis* / *amyloliquefaciens* activity



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Impressions from field experience



Concluding remarks

◇ Is there more to mBCAs than their mere “primary” mode of action?

✓ Yes.

◇ Inconsistency in efficacy may be due to gaps in knowledge/exploitation of mode of action?

✓ Yes.

◇ Can “additional” modes of action help to improve pest control?

✓ Yes.

Integrated Pest Management Principles

“Before taking any pest control action, **IPM** first sets an **action threshold**, a point at which pest **populations** or environmental conditions indicate that pest control action must be taken.”

EPA, 2012. Integrated Pest Management (IPM) Principles. <http://www.epa.gov/opp00001/factsheets/ipm.htm>

... any drawbacks ???

Annex I inclusion / registration ???

Special thanks are due to:

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- **the organizers**

- **you for your attention!**