# Mating behaviour and mating control (in farmed insects), what can we learn from biological control?


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29-31 January 2025 | Athens, Greece

INSECT GENETICS IMProvement IMPlementation IMPact

EAAP European Federation of Animal Science

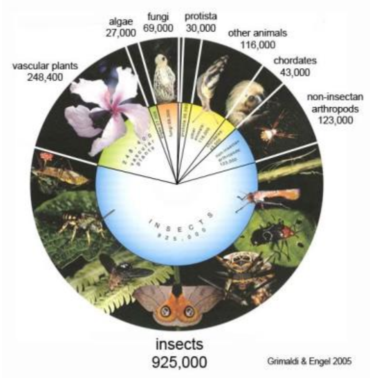
cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

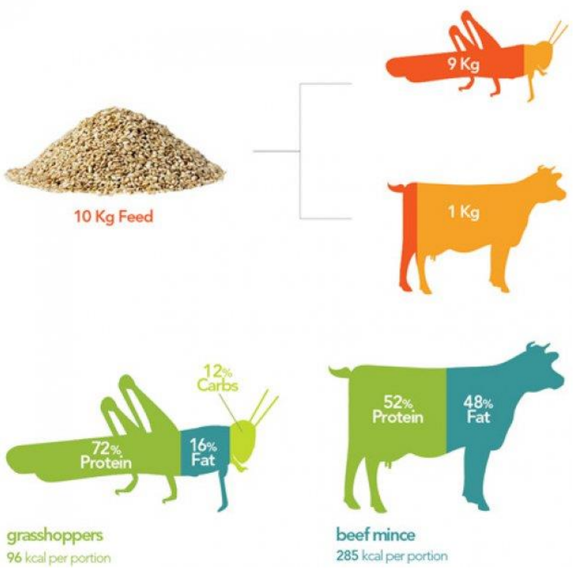
CESAM CENTRE FOR ENVIRONMENTAL AND MARINE STUDIES

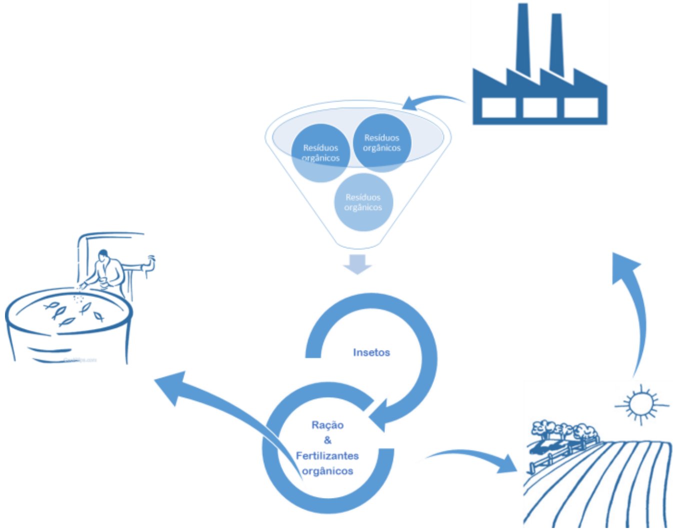
dbio universidade de aveiro departamento de biologia

ecomare universidade de aveiro laboratório para a inovação e sustentabilidade dos recursos marinhos

# SUStainable use of Insect protein in aquaculture feed



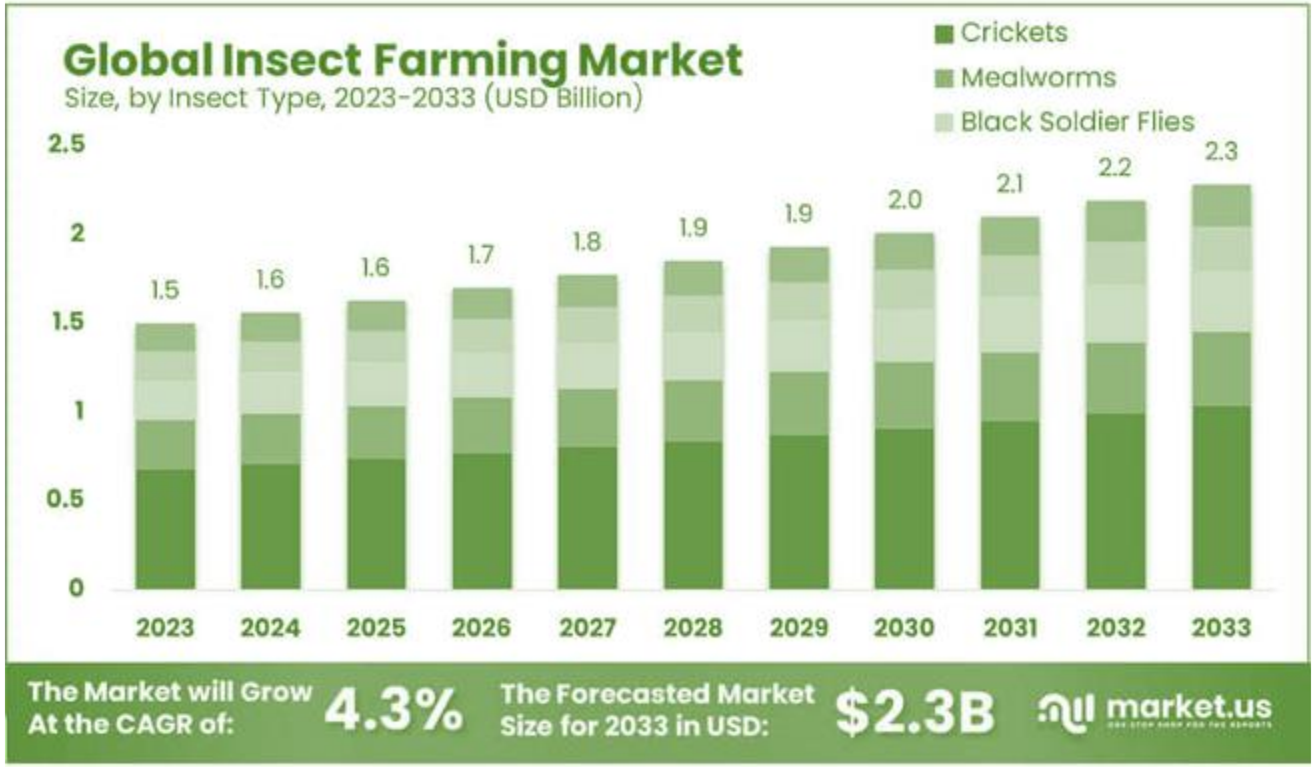





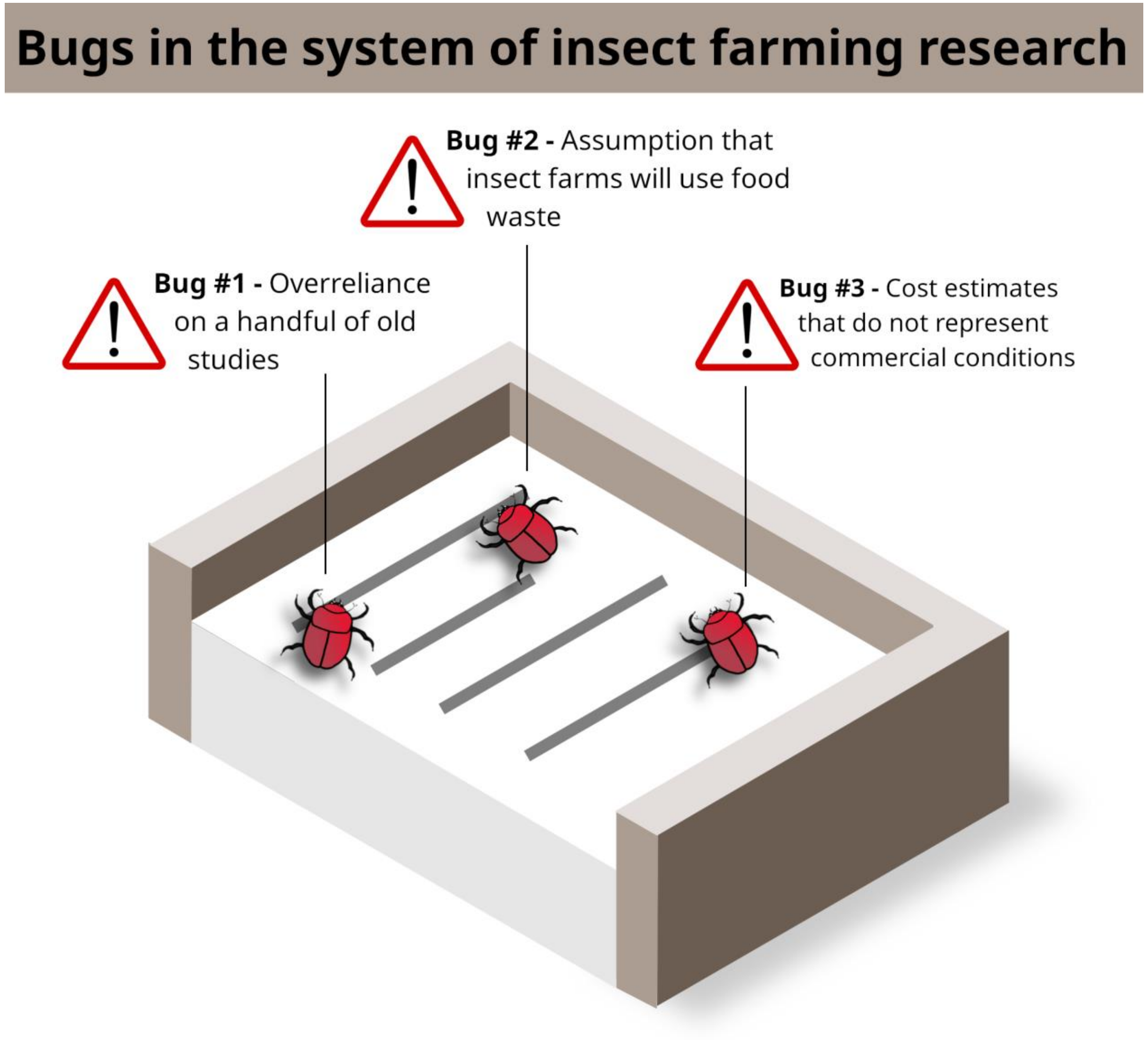
Data source: FAO's report "Edible Insects: future prospects for food and feed security"

(Source: Entomological Gastronomy, 2015; information from FAO's report "Edible Insects: future prospects for food and feed security").

# Global Insect Farming Market



# Bugs in the system




Biteau, C., Bry-Chevalier, T., Crummett, D., Ryba, R., & Jules, M. S. (2024). Insect-based livestock feeds are unlikely to become economically viable in the near future. *Food and Humanity*, *3*, 100383.

# Bugs in the system

Eurogroup for Animals - Position Paper - October 2021
Insect farming: a false solution for the EU's food system

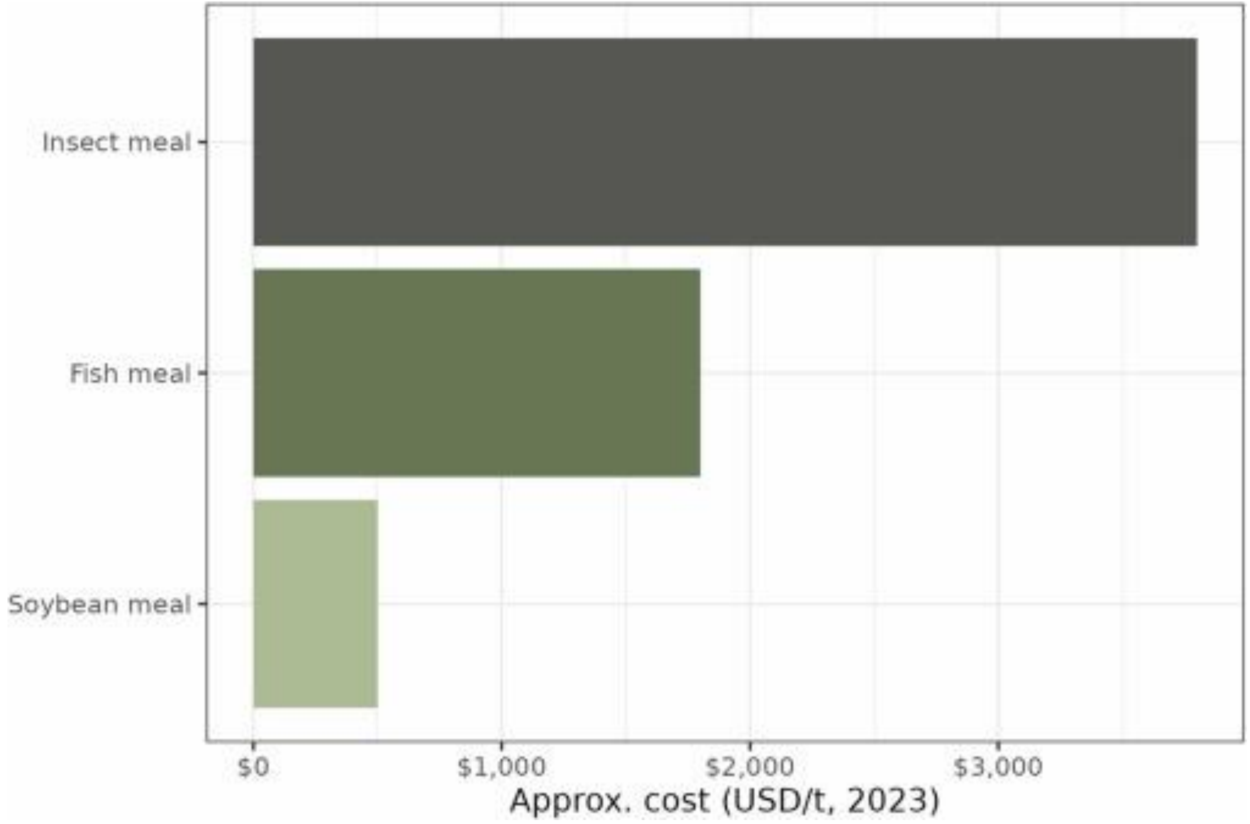
**Environmental impact of insect farming compared to soybean and rapeseed meal.**

| | | Soybean oil | | Soybean meal | |
|---|---|---|---|---|---|
| **Category** | *Unit* | *Black Soldier Fly* | *Yellow Mealworm* | *Black Soldier Fly* | *Rapeseed* |
| **Climate Change** | Kg $CO_2$ eq | +20% | +191% | +191% | -63% |
| **Energy use** | MJ | -8% | +268% | +2070% | -25% |

*Source: Liverød, Tonje. Life cycle assessment of insect production based on Norwegian resources. 2019.*

# Bugs in the system

Production cost estimates per ton for various animal meals

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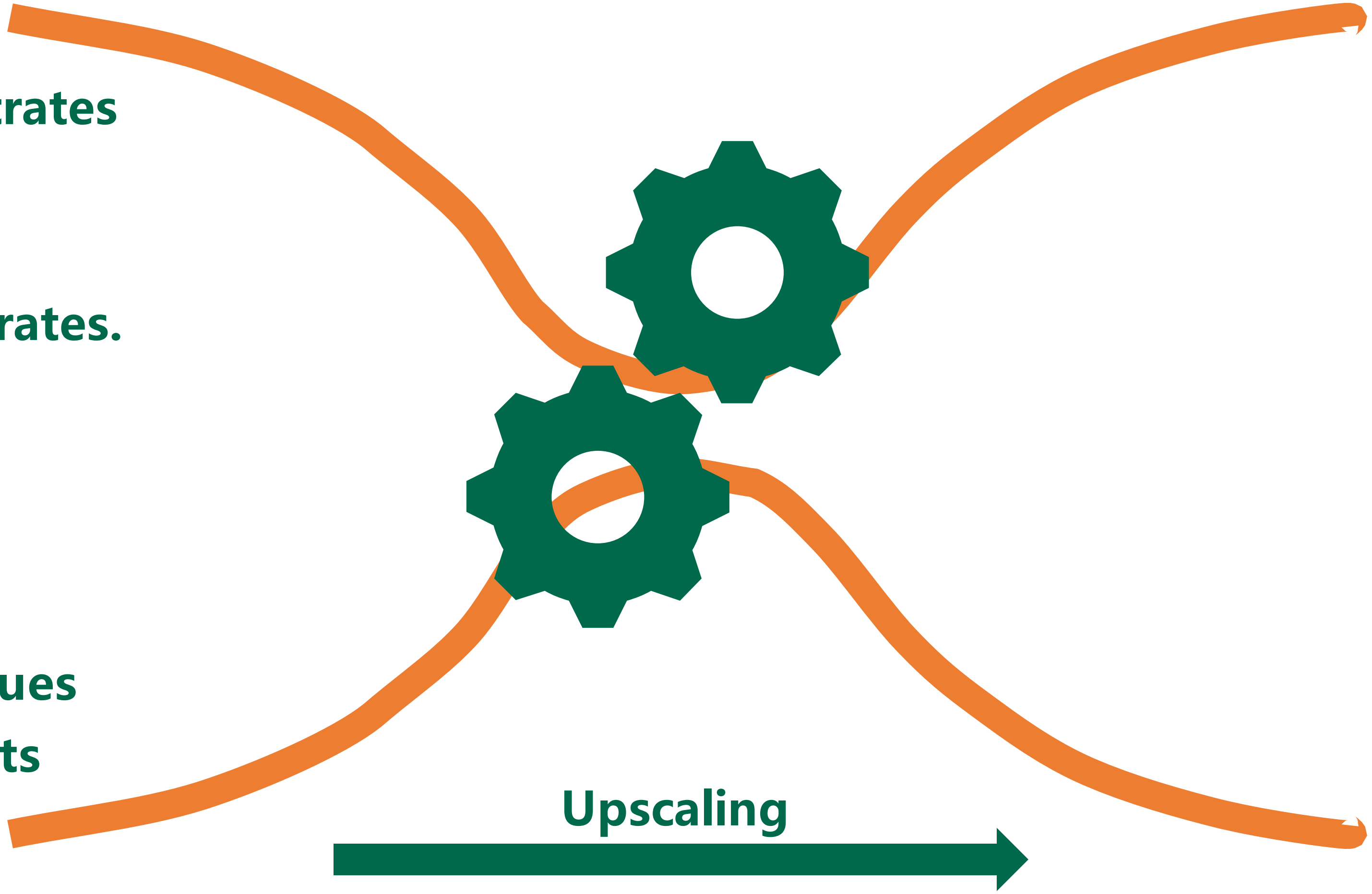
# Direct and indirect biological barriers hindering the upscaling of insect production capacity

**Need high quality insect feeding substrates**
**Knowledge on which species to rear**
**optimal rearing conditions**
**Most favourable composition of substrates.**
**Need for automation**
**Challenging product development and marketing**
**Deliver a stable supply of products**
**Regulatory uncertainty**
**Slow development production techniques**
**Lack of expertise on operational aspects**



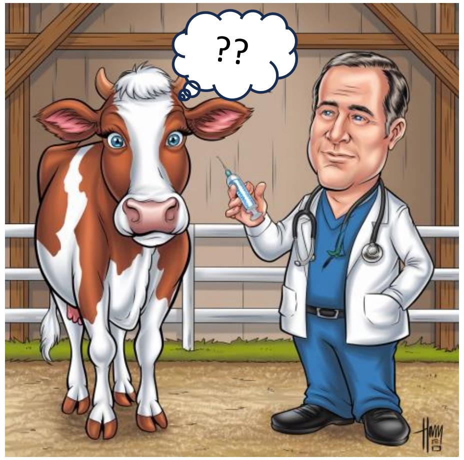

Yang, Y., & Cooke, C. (2021). Exploring the barriers to upscaling the production capacity of the edible insect sector in the United Kingdom. *British Food Journal*, *123*(4), 1531-1545
Maillard, F., et al.. (2018). Mealworm larvae production systems: management scenarios. *Edible insects in sustainable food systems*, 277-301.

# Selective breeding

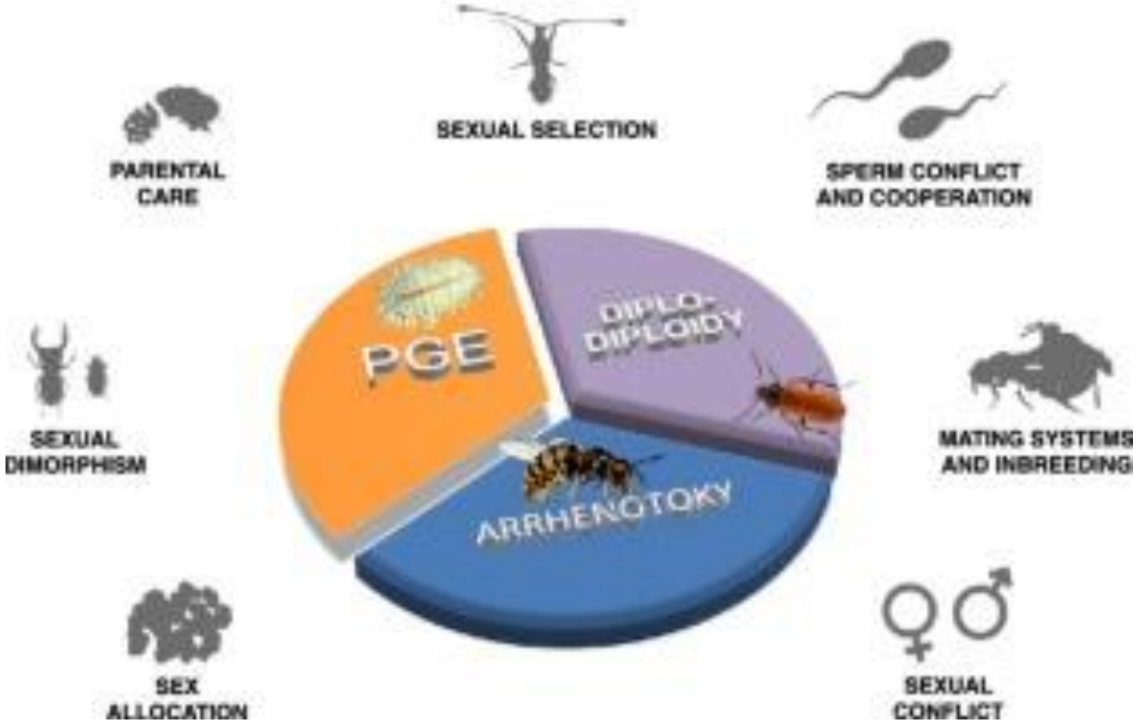
Selective breeding requires manipulation and management of the entire rearing and breeding cycle, this includes:

- manipulation of rearing conditions
- **mating**
- reproduction including **reproductive behaviour**

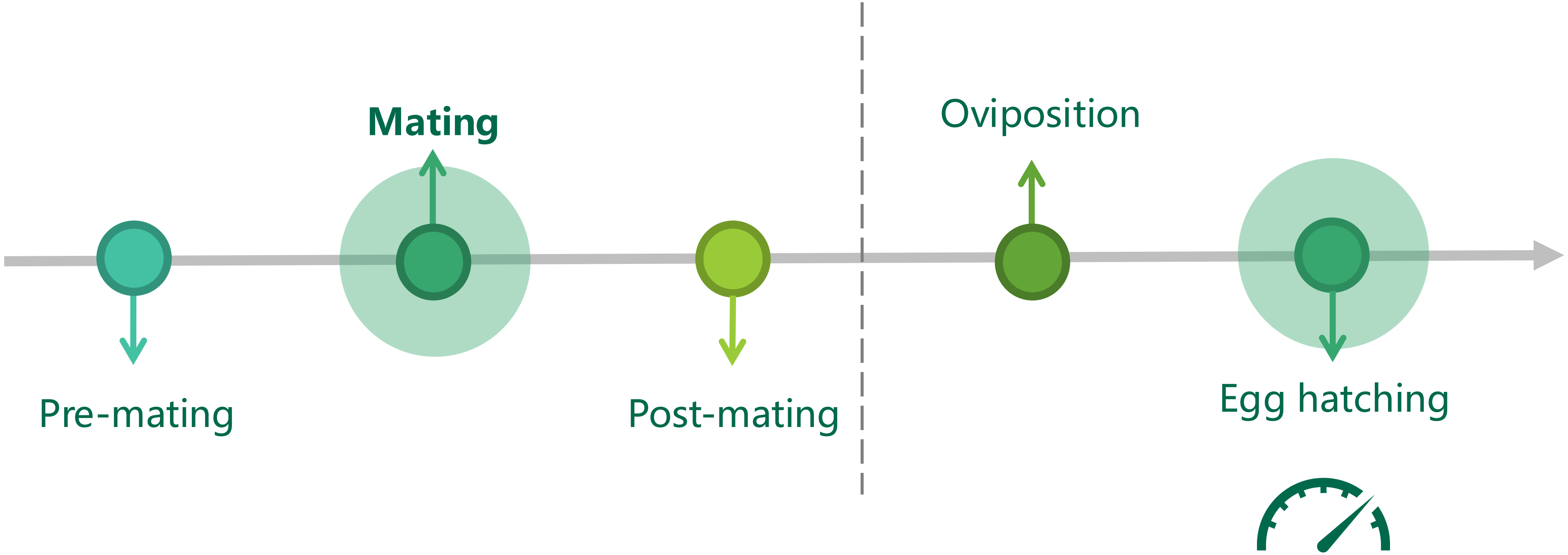
## Conventional animal breeding practices




## Reproductive ecology of Arthropods

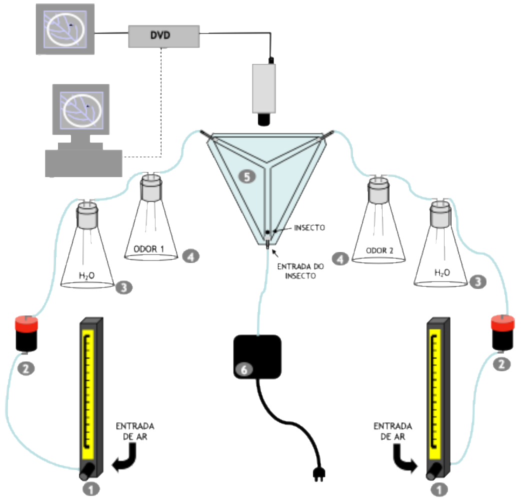


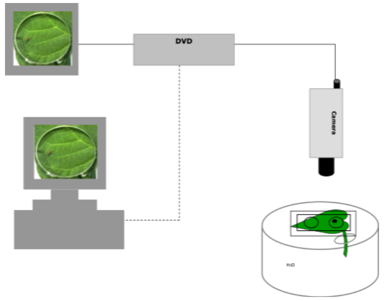
# Mating

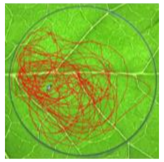


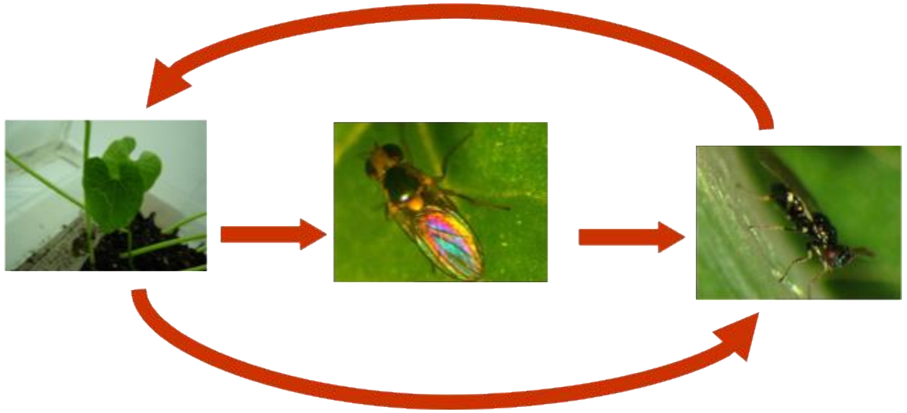
# Tritrophic system: Plant host-Pest -Parasitoid

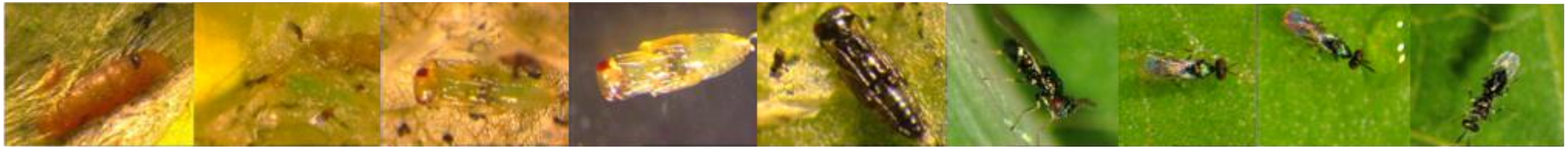
***Vicia faba*– *Liriomyza* sp. – *Diglyphus isaea* (Hymenoptera, Eulophidae)**







Ameixa, O., Almeida, L., Gonçalves, A., & Neto, L. (2007). Feeding behavior of Liriomyza huidobrensis (Blanchard) and L. trifolii (Burgess) adults on bean leaves. *Journal of insect behavior*, *20*, 137-155.

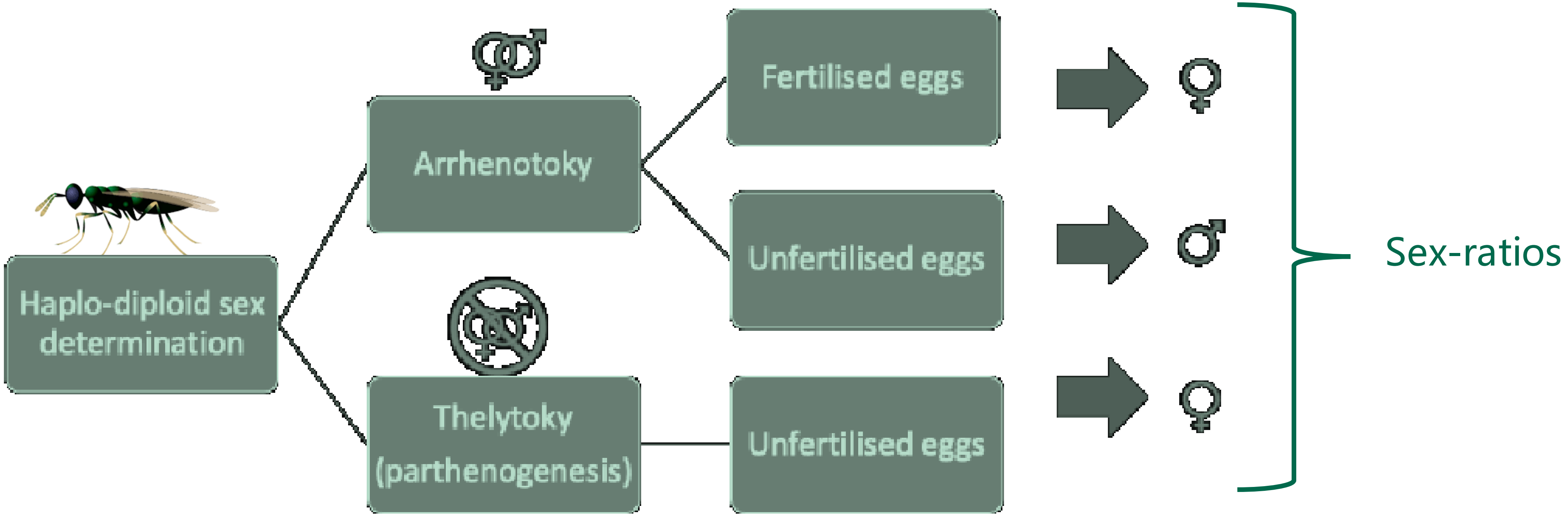
↓ 

↓ ♀ 

Biased Sex-ratios

Ameixa, O., Almeida, L., Gonçalves, A., & Neto, L. (2007). Feeding behavior of Liriomyza huidobrensis (Blanchard) and L. trifolii (Burgess) adults on bean leaves. *Journal of insect behavior*, *20*, 137-155.

# Hymenopteran parasitoids generally show haplo-diploid sex determination




Ye, F. Y., Zhu, C. D., Yefremova, Z., Liu, W. X., Guo, J. Y., & Wan, F. H. (2018). Life history and biocontrol potential of the first female-producing parthenogenetic species of Diglyphus (Hymenoptera: Eulophidae) against agromyzid leafminers. Scientific Reports, 8(1), 3222.

Biological Control
Volume 19, Issue 1, September 2000, Pages 77-93

Commentary

# Sex Ratios of Commercially Reared Biological Control Agents

George E. Heimpel, Jonathan G. Lundgren

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## Abstract

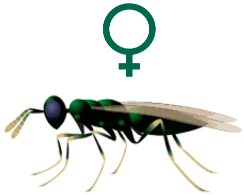
We purchased samples of 27 parasitoids, six coccinellid beetles, and the predatory midge *Aphidoletes aphidimyza* (Rondani) from commercial insectaries and scored the sex ratios from groups of approximately 200 individuals from each of these samples. Parasitoid sex ratios ranged from all female to 0.77 (proportion males), and none of the predator sex ratios differed significantly from 0.5. Among the parasitoids, we found no significant effect of taxonomic affiliation (family, superfamily) or life history (gregarious vs solitary development) on the sex ratio. The pteromalid parasitoids *Muscidifurax raptorellus* (Kogan and Legner), *M. zaraptor* (Kogan and Legner), and *Nasonia vitripennis* (Walker) and the eulophid *Diglyphus isaea* (Walker) all had significantly male-biased sex ratios, and an additional five species that did not have male-biased sex ratios had sex ratios that had a higher proportion of males than reported in the literature. These were *Cotesia plutellae* Kurdjumov (Braconidae), *Dacnusa sibirica* Telenga (Braconidae), *Eretmocerus* nr. *californicus* Howard (Aphelinidae), *Trichogramma brassicae* Bezdenko (Trichogrammatidae), and *Pediobius foveolatus* (Crawford) (Eulophidae). This suggests that it may be possible to increase the proportion of females produced by these species under conditions of commercial rearing. In the rest of the species studied (74% of species purchased), sex ratios either conformed to most published reports or had a higher proportion of females. We discuss the sex ratios of each species or group of species separately and review potential explanations for the sex ratios that we found, as well as implications of the results for mass rearing.

- Sex ratios produced by *D. isaea* females are **highly dependent on host size**, with relatively smaller hosts producing disproportionately more male offspring (P. J. Ode and K. M. Heinz, unpublished data).
- **Population-level sex ratios can be male biased under conditions of mass and laboratory rearing**, presumably due in part to the effects of host size (Heinz and Parrella, 1990a,b; P. J. Ode and K. M. Heinz, unpublished data),
- P. J. Ode and K. M. Heinz have shown that **female-biased sex ratios can be obtained by host size manipulation.**

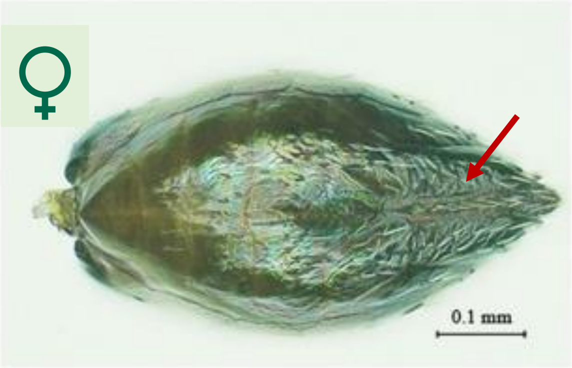
**Host size ⇔ Substrate quality**

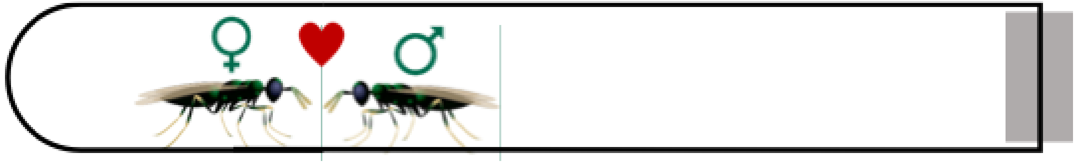
Heimpel, G. E., & Lundgren, J. G. (2000). Sex ratios of commercially reared biological control agents. *Biological Control*, *19*(1), 77-93.

# Arrhenotoky



Biased Sex-ratios



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# Tritrophic system: Plant host-Pest -Predator

*Vicia faba – Acyrthosiphon pisum – Coccinella septempunctata*

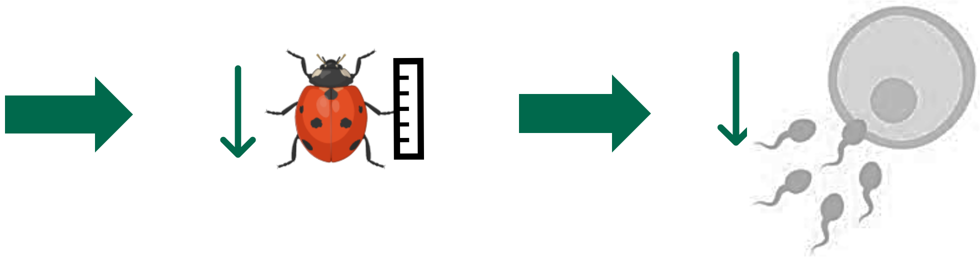
# When good diet is not available

**For mass rearing alternatives diets include several types of diets have been tested with several trade-offs**

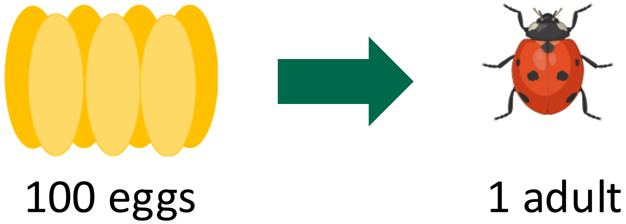
*Ephestia kuehniella* eggs

- Slightly lower fecundity (egg production) compared to those reared on aphids.
- Not as palatable or stimulating as live aphids.
- Can be more expensive than rearing aphids, especially for large-scale operations.

# When good diet is not available

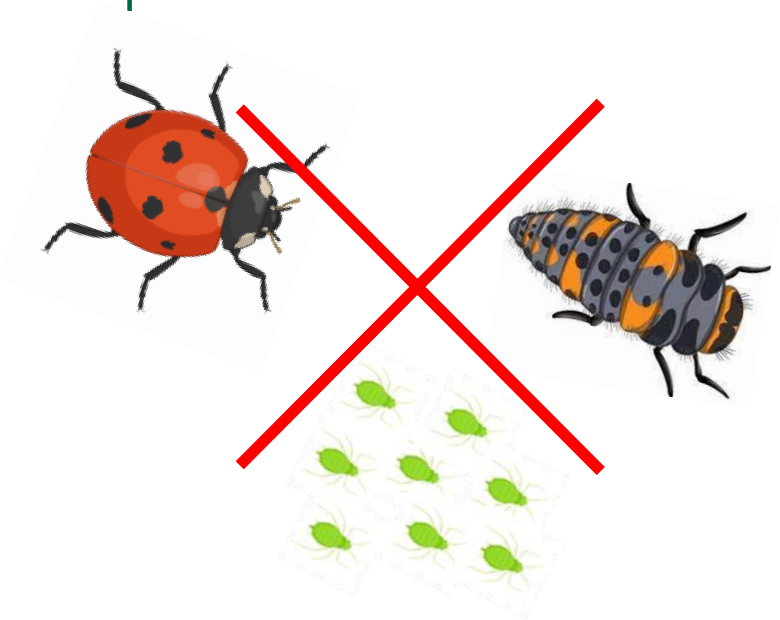


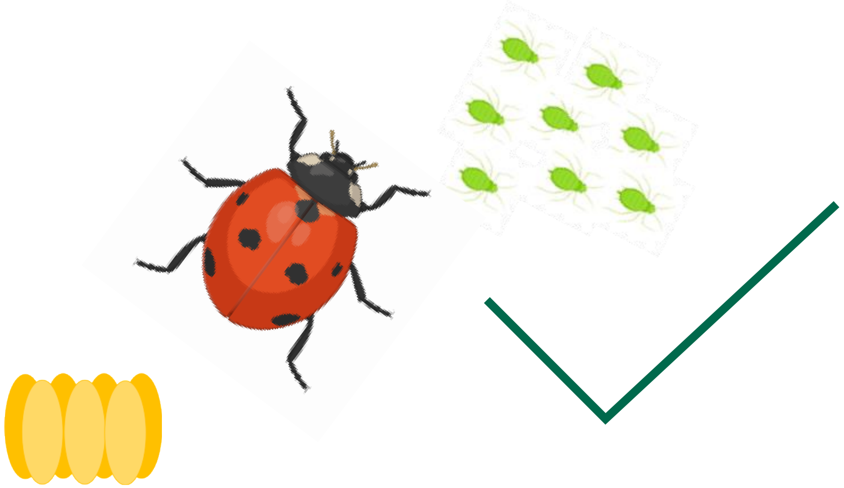
In aphidophagous ladybird mortality rate is around 99%



# Behavioural constrains to oviposition

Adult ladybirds are reluctant to lay eggs where their conspecific larvae is present






Magro, A., Téné, J. N., Bastin, N., Dixon, A. F., & Hemptinne, J. L. (2007). Assessment of patch quality by ladybirds: relative response to conspecific and heterospecific larval tracks a consequence of habitat similarity?. *Chemoecology*, *17*, 37-45.

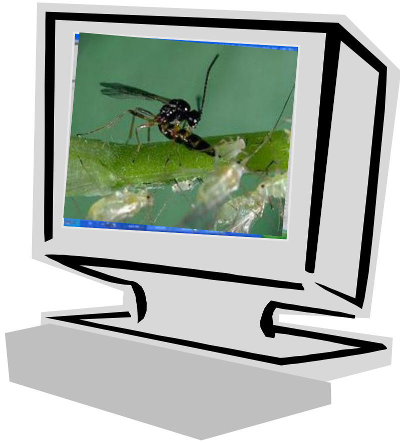
RŮŽIČKA, Z. 2006. Oviposition-deterring effects of conspecific and heterospecific larval tracks on Cheilomenes sexmaculata (Coleoptera: Coccinellidae). Eur. J. Entomol. 103:757–763.

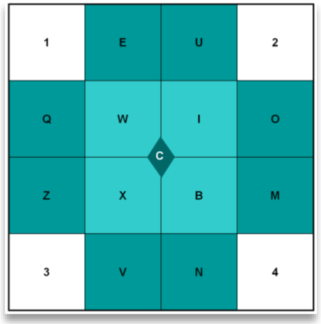
Lommen, S. T., Middendorp, C. W., Luijten, C. A., van Schelt, J., Brakefield, P. M., & de Jong, P. W. (2008). Natural flightless morphs of the ladybird beetle Adalia bipunctata improve biological control of aphids on single plants. Biological Control, 47(3), 340-346.

# Response to sexual and alarm semiochemicals

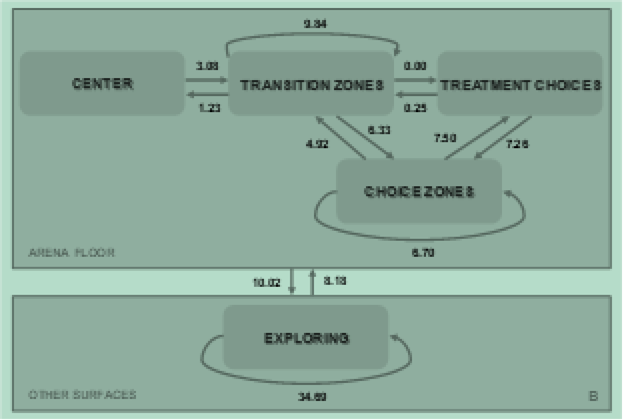
*A. colemani* is a polyphagous aphid parasitoid, that is frequently used in biological control of various aphid pests

- Mated females with no previous experience, 2-days old
- 3 groups of semiochemicals concentrations were tested (A, B, C)
- 30 replicates



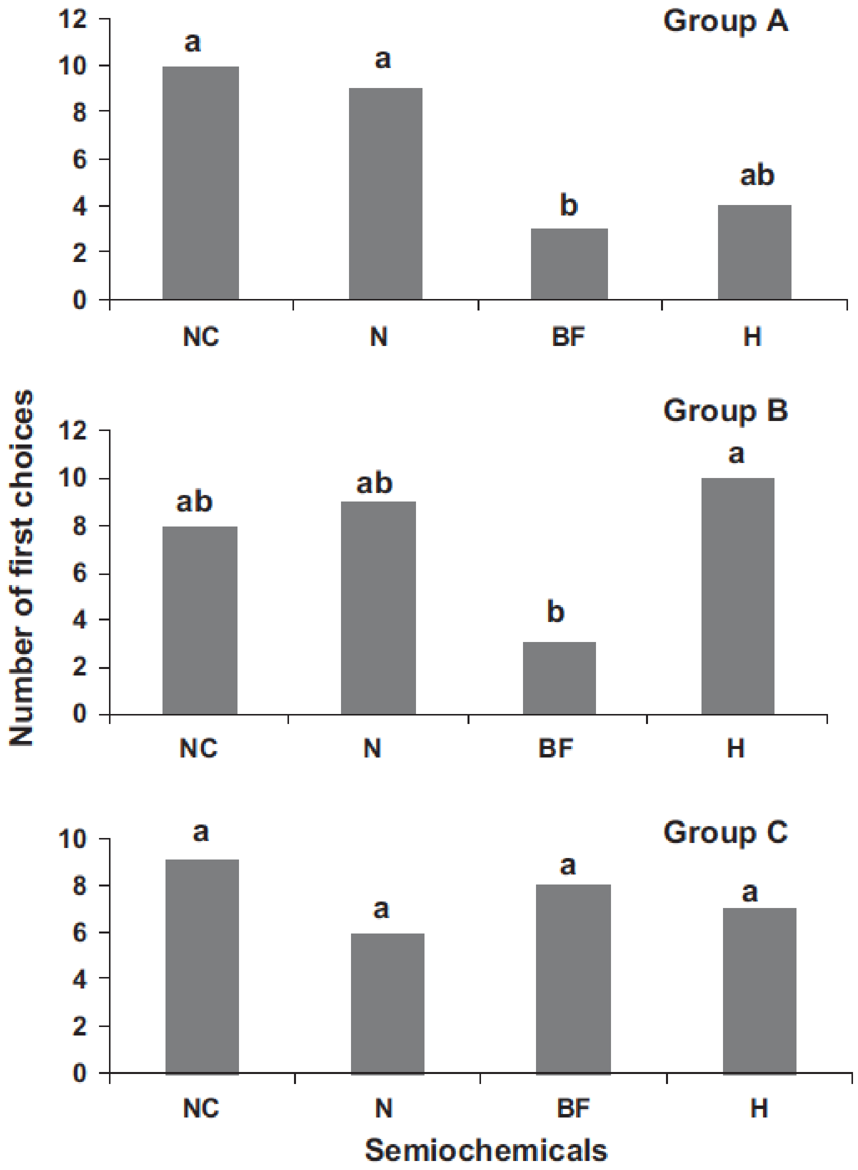



| Group | Semiochemicals (mg /ml) | | |
|---|---|---|---|
| | (E)-β- farnesene (BF) | nepetalactone (N) | *Nepeta cataria* (NC) |
| A | 1 | 1 | 1 |
| B | 0.1 | 0.5 | 0.5 |
| C | 0.01 | 0.1 | 0.1 |




Ameixa, O. M. C. C., & Kindlmann, P. (2012). Effect of synthetic and plant-extracted aphid pheromones on the behaviour of Aphidius colemani. *Journal of applied entomology*, *136*(4), 292-301.

# Response to more specific cues

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# Take home messages

- Directly influences, yield, population dynamics, genetic variability, and the overall sustainability of insect production systems.
- Essential for maximizing reproductive efficiency in insect farming
- The diversity of strategies and behaviors can influence the rearing

## Please join our COST Action 22140 Insect-IMP: Improved Knowledge Transfer for Sustainable Insect Breeding.

### WG2: Mating control

# Thank you!


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INSECT-IMP

EAAP European Federation of Animal Science

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY


*Acknowledgement go to the funding from the COST Action 22140 Insect-IMP: Improved Knowledge Transfer for Sustainable Insect Breeding.*