Pheromone-based control of insect pests in berry production

Glenn Svensson

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LUND UNIVERSITY

Major challenges facing pest control globally

- *Up to one third of worldwide food production is destroyed by insects, not including the damage done in storage.*
- *During decades of insecticide use, a permanent decrease in the abundance of targeted insect populations never has been achieved.*
- *Many of our top agricultural pests instead have been created by the use of pesticides that often have a stronger effect on natural antagonists than on the target species, and also because of widespread insecticide resistance.*

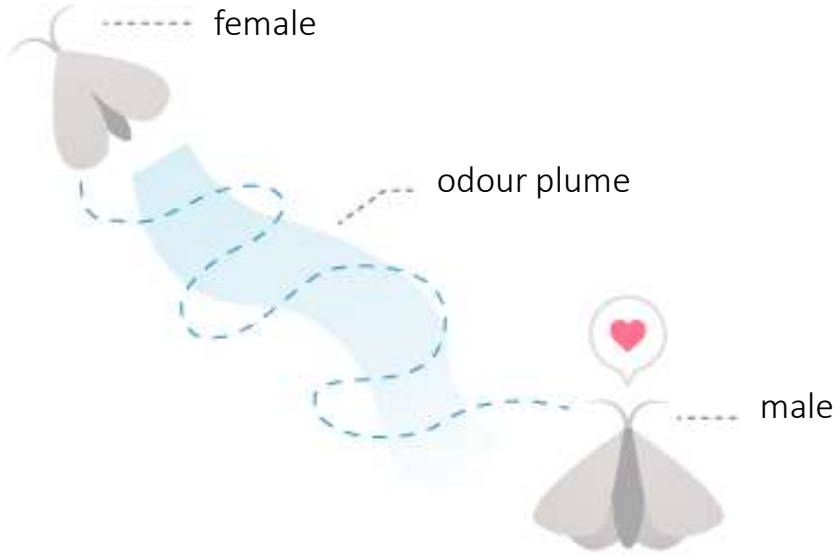
(Witzgall et al. J Chem Ecol 2010)

Traditional pest control using insecticides

- Toxic treatment
- Not easily degradable compounds
- Non-specific – also beneficial species are affected e.g. natural enemies and pollinators
- Evolution of resistance in target species

Conclusion: There is an urgent need to replace pesticide use in agriculture/forestry and implement Integrated Pest Management (IPM).

Sexual communication in moths



- The female moth releases a species-specific odour (sex pheromone) to attract conspecific males over large distances
- Synthetic pheromones can be used in traps for detection and monitoring of pest populations, and also for direct control as part of IPM

Why using pheromones in IPM?

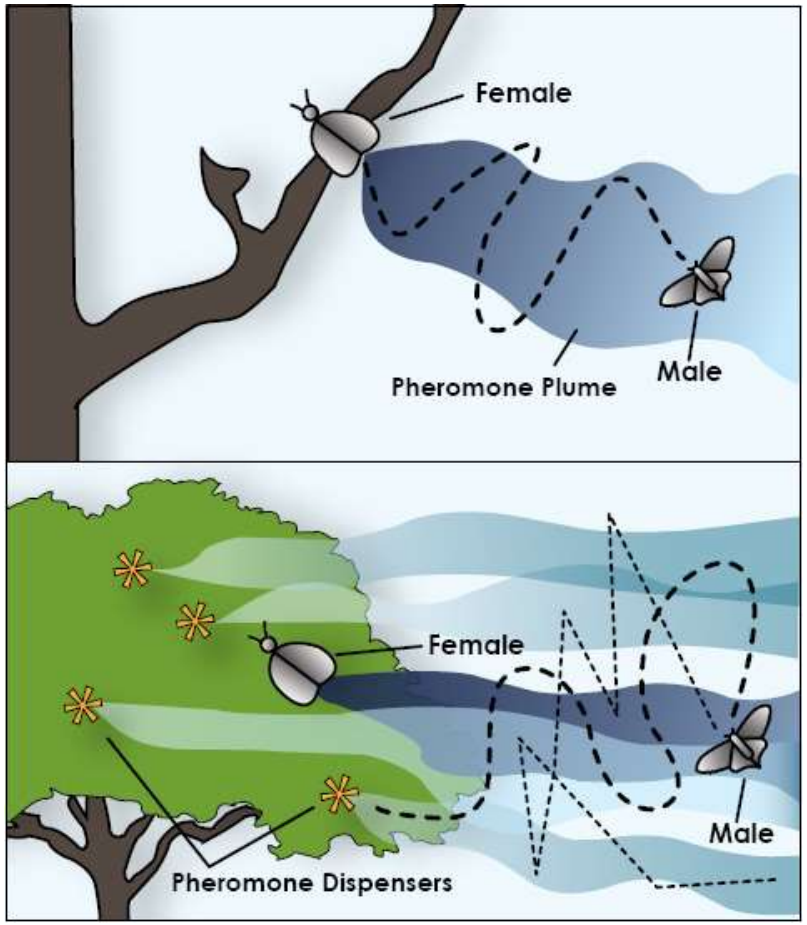
- Non toxic compounds
- Easily degradable
- Species-specific (no impact on beneficial insects)
- Small amounts of active compounds used
- Low risk of resistance evolution

The global agricultural pheromones market size was estimated at USD 3.6 billion in 2022, and projected to reach USD 8.3 billion by 2027!

Pheromone-based methods in pest management

- Monitoring traps
- Mass trapping
- Attract and kill
- Mating disruption (MD)

MD in moths



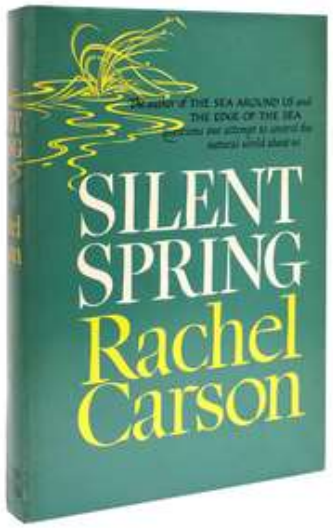
Distribution of dispensers releasing high doses of synthetic sex pheromone will reduce the ability for the males to locate calling females

= fewer matings in treated area

= lower level of crop infestation

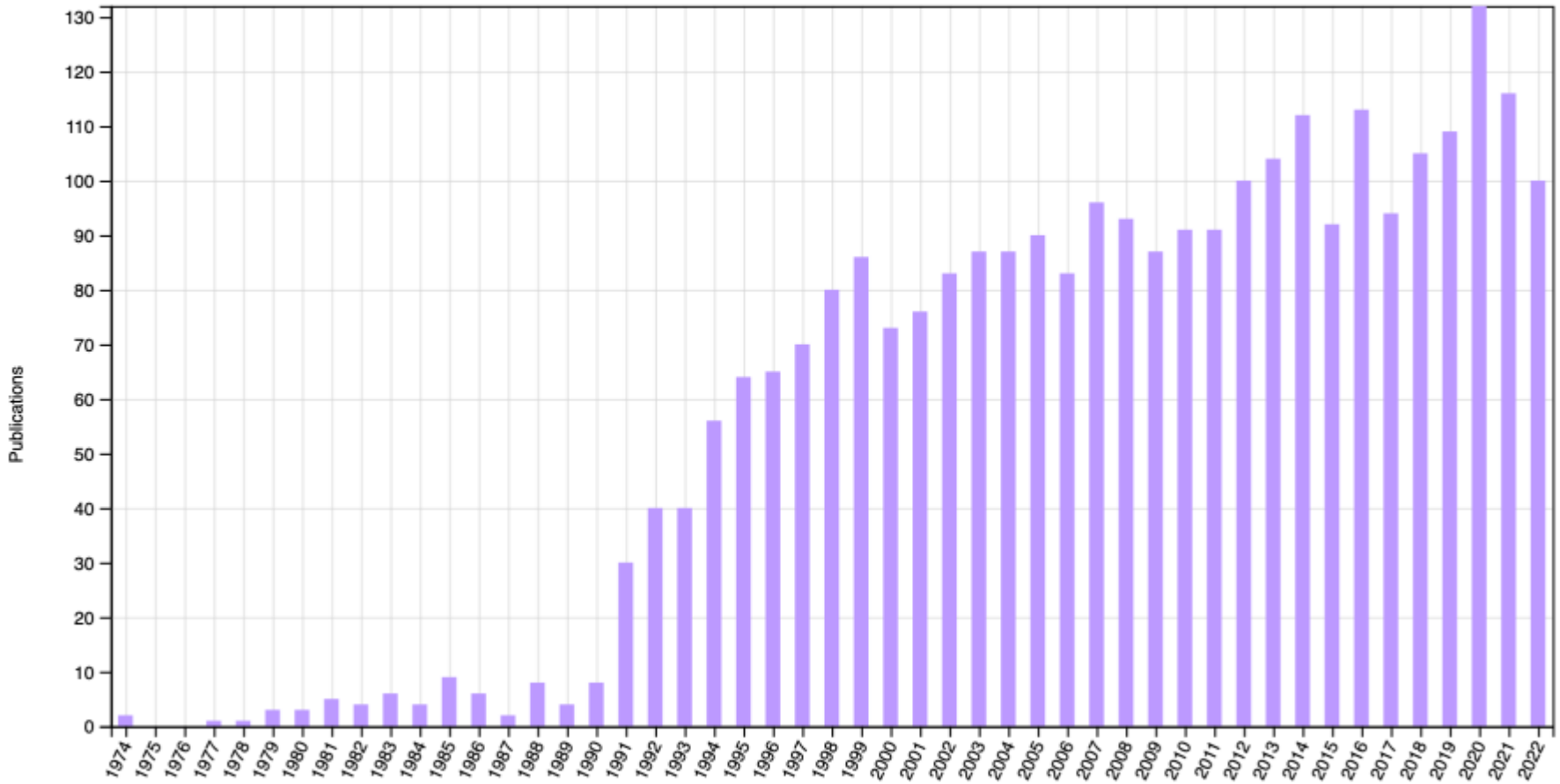
MD in moths

In her classic book Silent Spring (1962), published a few years after the first identification of an insect pheromone, Rachel Carson describes the phenomenon:



"The aim is to confuse the male moth and alter the normal behaviour so that, in the welter of attractive scents, he cannot find the true scent trail leading to the female (p. 247).

Number of publications about mating disruption
(Web of Science search 2023-01-16)



Increased use of MD globally

Table 1. Growth in use of mating disruption products globally

Pest species	Principle crop	Area treated (ha)		
		2002[a]	2012[b]	% Change
Lymantria dispar	Deciduous forest	60,000	200,000	233
Cydia pomonella	Pome fruit, Walnut	120,000	220,000	83
Grapholita molesta	Stone and Pome fruit	50,000	60,000	20
Lobesia botrana	Grape	41,000	150,000	266
Eupoecilia ambiguella	Grape	32,000	60,000	88
Endopiza viteana	Grape	1,000	1,000	0
Chilo suppressalis	Rice	4,000	8,000	100
Leafrollers (Tortricidae)	Tea, Pome fruit Peach, Grape	24,000	15,000	−38
Synanthedon spp.	Peach, Apricot, Black current	5,000	6,000	20
Zeuzerina pyrina	Pear, Olive	2,000	3,000	50
Plutella xylostella	Cabbage	2,000	2,000	0
Keiferia lycopersicella	Tomato	10,000	2,000	−80
Pectinophora gossypiella	Cotton	55,000	19,000	−66
Others	Vegetables, Apple, Peach, Turf	27,000	10,000	−63
TOTAL		433,000	756,000	75

[a] Data from Cardé (2007).
[b] Data courtesy of Pacific Biocontrol and Shin-Etsu Corporation.

Miller & Gut (2015). Env. Entomol. 44:427-453.

Challenges when using pheromone-based pest control

- High cost of pheromone products in comparison with conventional insecticides
- Pheromone products require skilled labour
- Species-specific action of pheromones can serve as a disadvantage

Proposed mechanisms causing MD

- Competitive (no impairment of males/females/signal):
    - False-trail following (males track plumes from dispensers)
    - Induced allopatry (males aggregate near dispensers)
    - Induced arrestment (males reduce their search behaviour)

Pest-density-dependent

- Non-competitive (impairment of males/females/signal):
    - Peripheral adaptation/habituation [CNS])
    - Camouflage (plumes obscured by background cloud of pheromone)
    - Suppressed calling/mating (females alter their behaviour)
    - Induced allochrony (activity period shifted)

Pest-density-independent

Miller & Gut (2015). Env. Entomol. 44:427-453.

Factors determining the efficiency of MD

- The size and degree of isolation of crop field
- Population size of pest
- Quality of pheromone
- Type of dispenser (release rate)
- Density of point sources
- Placement (hight) of dispensers
- Other pests may increase in abundance

Dispensing systems for high release of pheromone

- Hand-applied reservoir-type dispensers
- Sprayable dispensers (microcapsules)
- Machine-applied formulations (SPLAT)
- Controlled release devices (puffers)

Pheromone-based mating disruption of the strawberry tortrix, *Acleris comariana*

Victoria Tönnberg
Berry advisor
HIR Skåne

Lene Sigsgaard
Plant biologist
Copenhagen University

Glenn Svensson

Department of Biology, Lund University

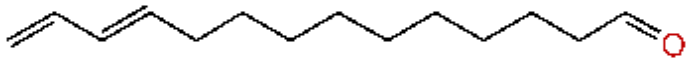
Stiftelsen Lantbruksforskning

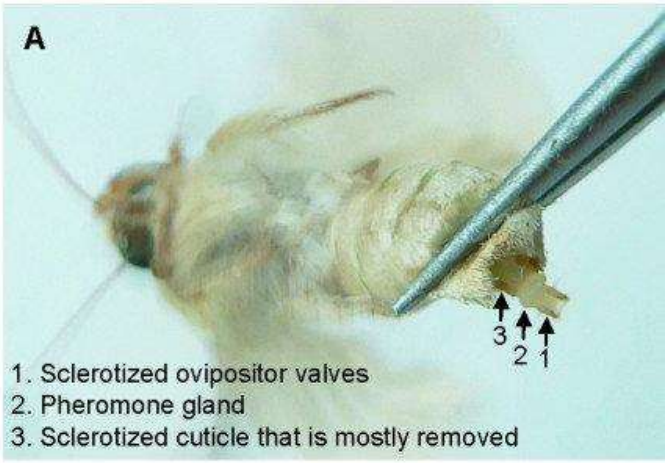
FORMAS

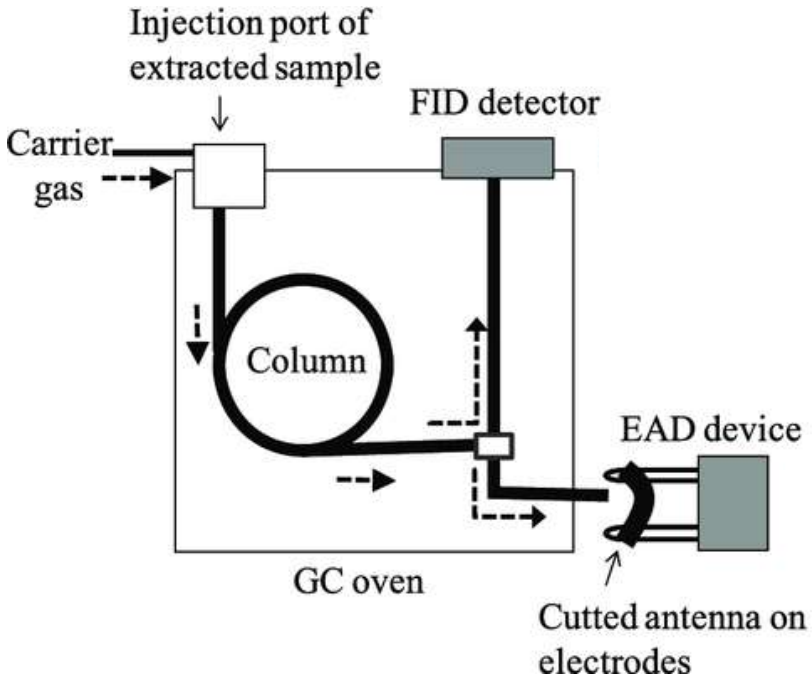
Acleris comariana (Tortricidae)

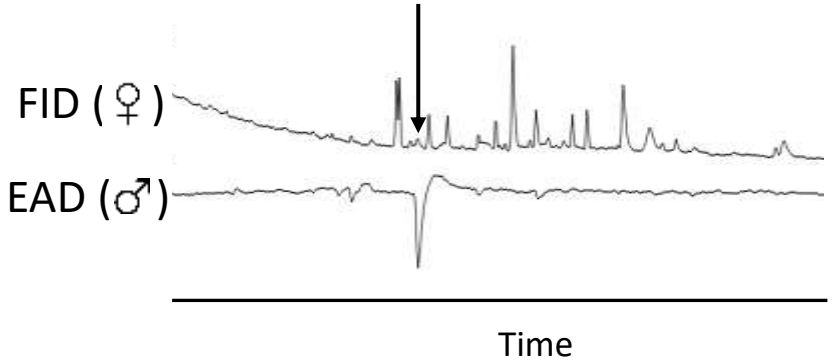
Major strawberry pest in Denmark and south Sweden

(E)-11,13-tetradecadienal sex pheromone of *A. comariana*



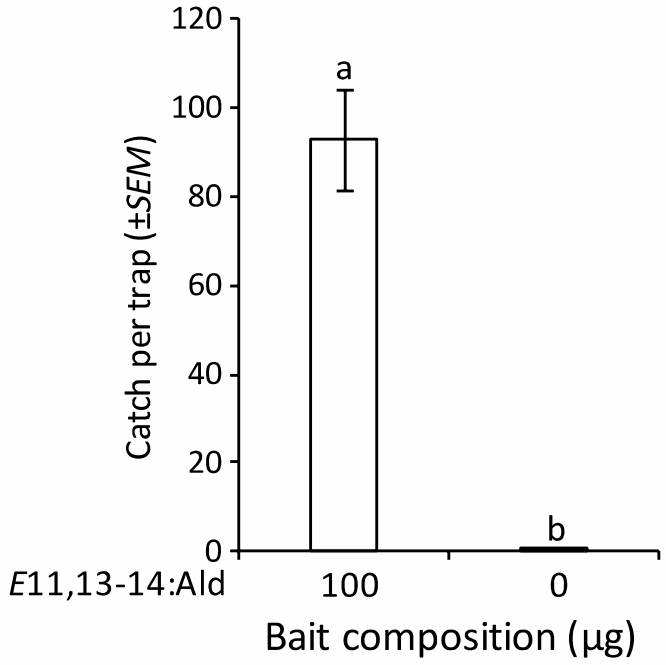






Svensson et al. (2019) J. Appl. Entomol. 143:535-541.

(E)-11,13-tetradecadienal sex pheromone of *A. comariana*



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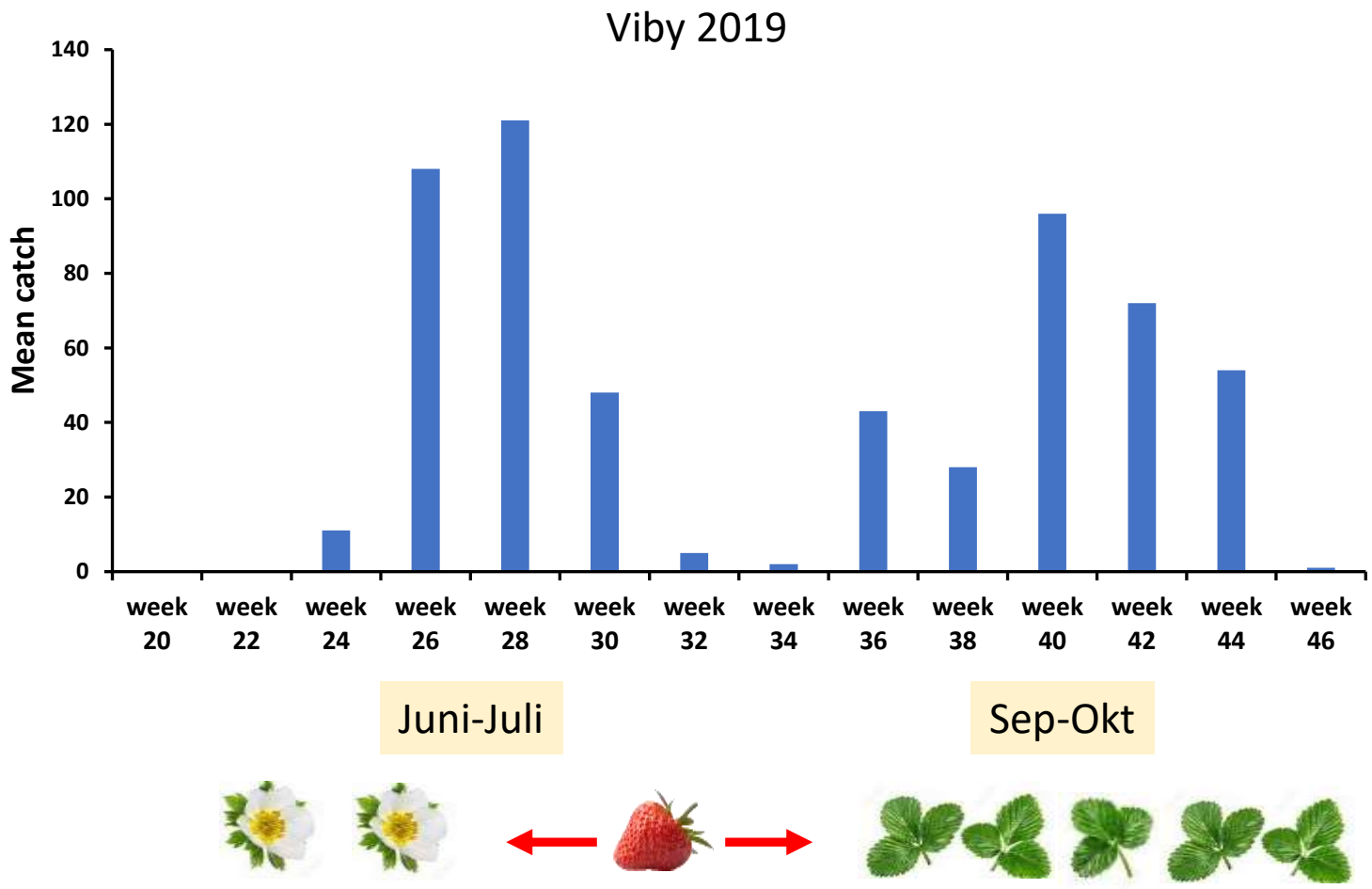
Flight phenology of the strawberry tortrix based on catches in pheromone traps



Standardized MD experiments: the same farmer and variety (Malwina)

Experiments 2020-2021

- In each field, 1 ha treatment plot and a control plot separated by at least 150 m
- 4 traps in each plot
- 10 x 10 matrix of dispensers
- Second application after 3 weeks
- Total dose av per ha: ≈7+7 g (2020), ≈0.7+0.7 g (2021)

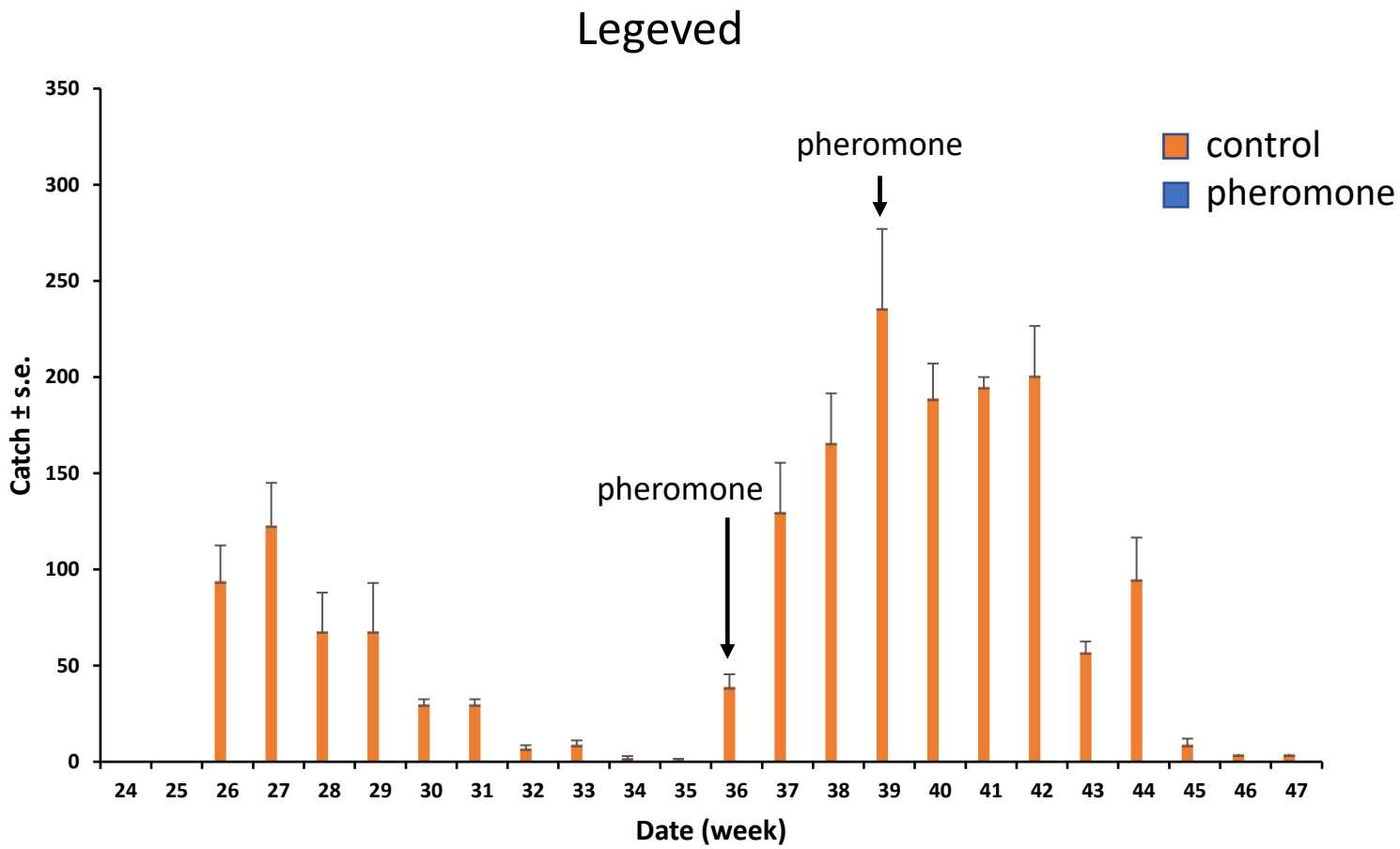
It works!

Catches control plot

Catches treatment plot

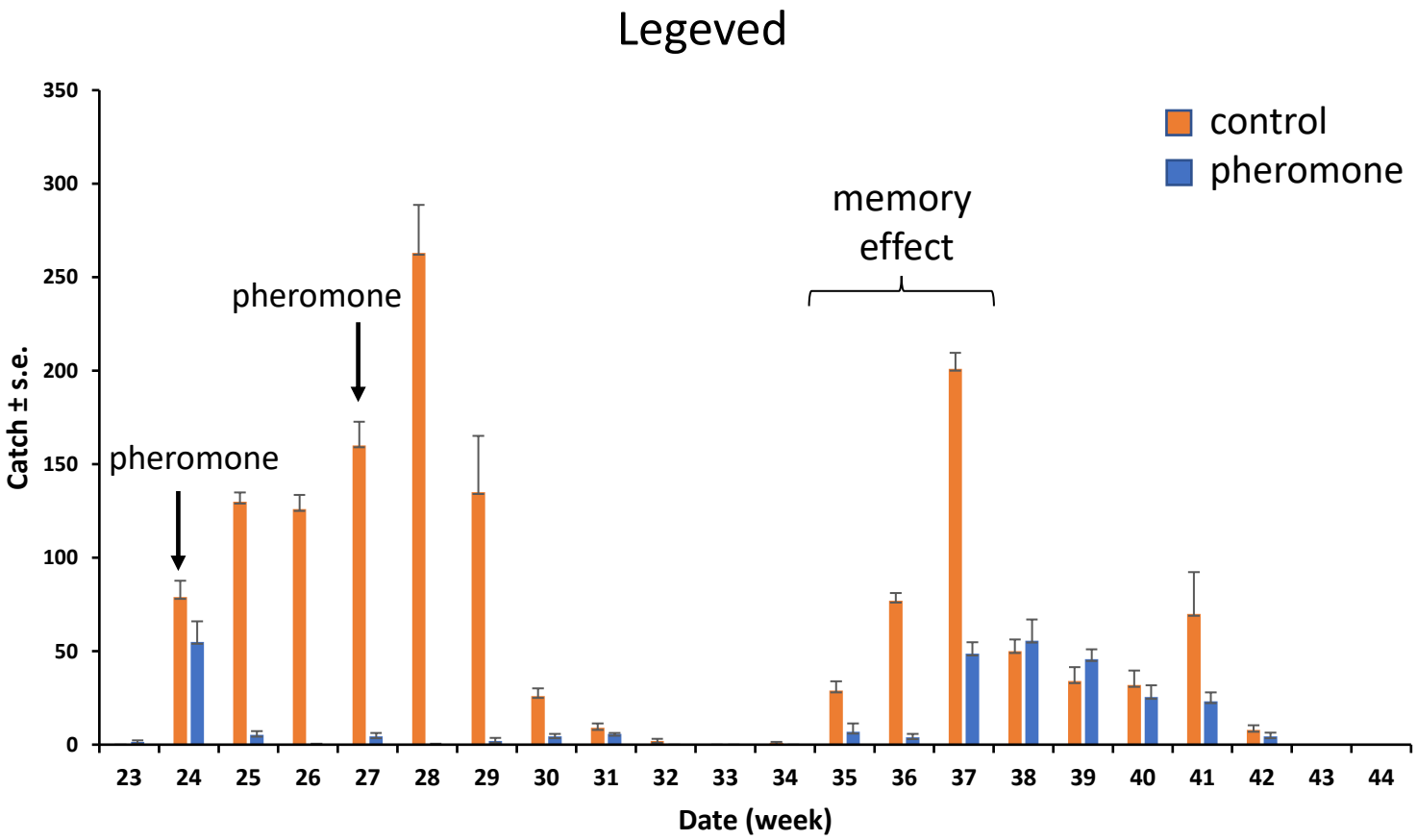
Experiments 2020 (7 + 7 g)

3664 males trapped in control plot
2 males trapped in treatment plot



Experiments 2021 (0.7 + 0.7 g)

3358 males trapped in control plot
82 males trapped in treatment plot

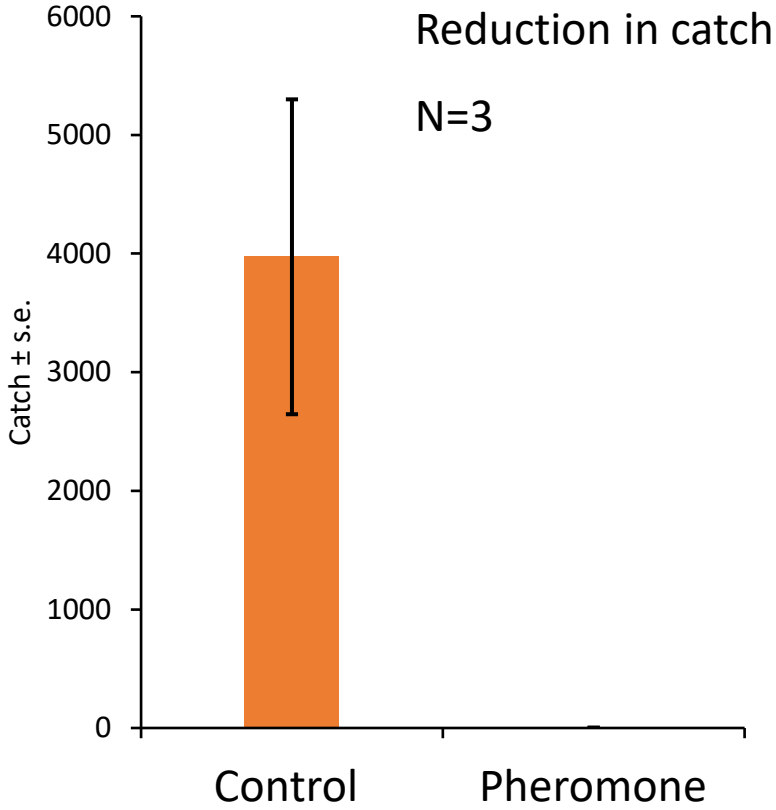


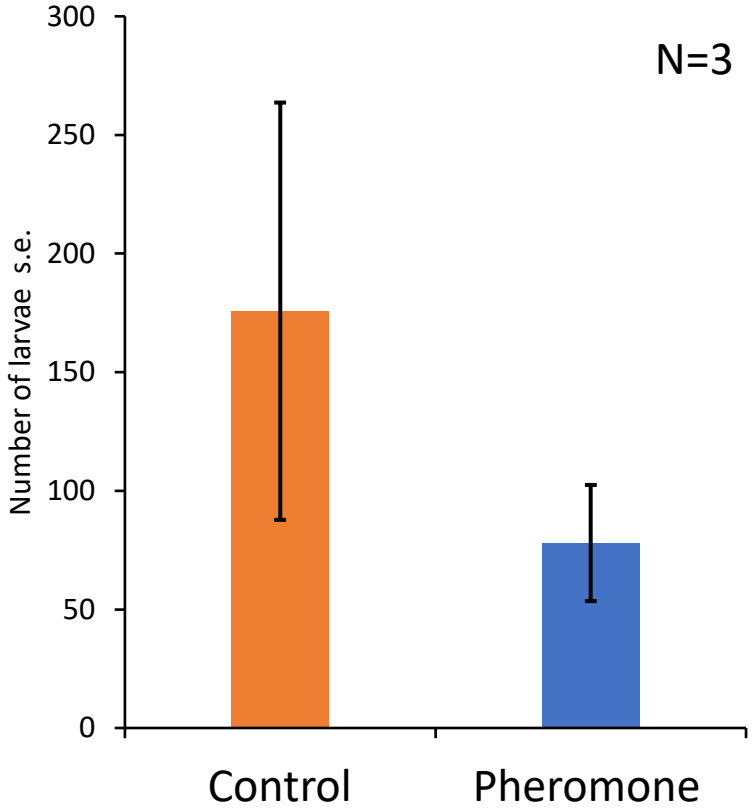
Catch of males and larval abundance 2020

2020: ≈7 g per ha

Reduction in catch: 99.9-100%

N=3



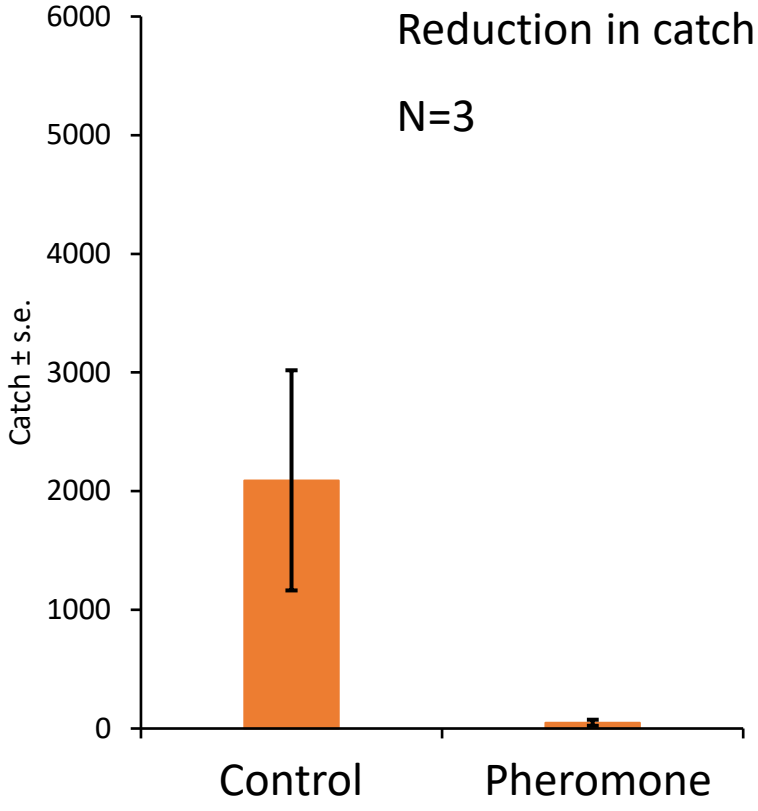


Catch of males and larval abundance 2021

2021: ≈0.7 g per ha

Reduction in catch: 97.6-99.6%

N=3



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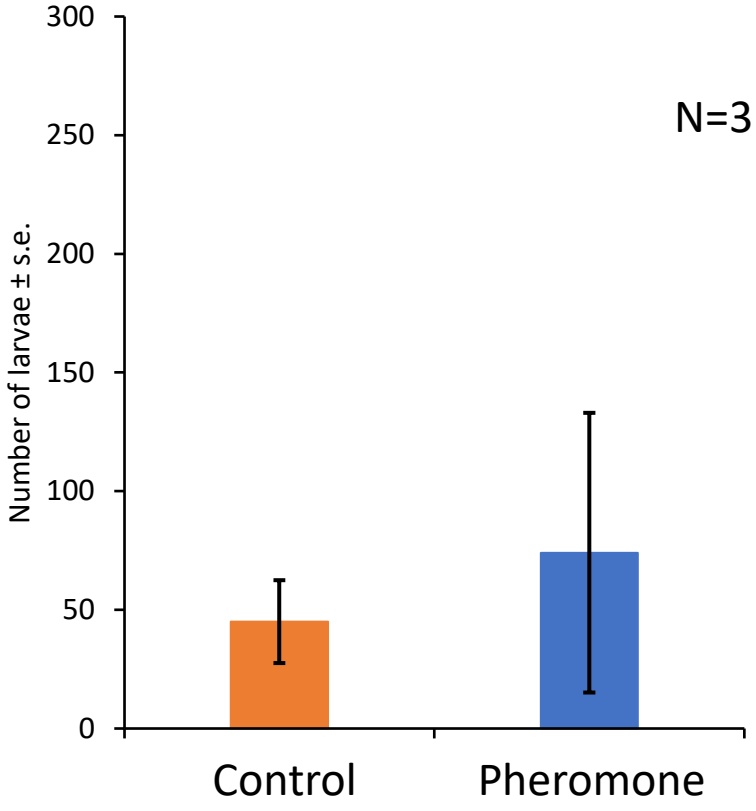

Why weak correlation between catch and larval abundance?

- A small part (<10%) of the field was treated
- Treatment of whole fields was not possible due to limited research budget (15 g pheromone – 60000 SEK!)
- Female moths cannot detect their own pheromone and are thus not affected by the treatment
- Female moths can mate in the other part the field and then disperse into the treated area and lay eggs
- Treatment of whole fields needed

Small amounts of pheromone used for *A. comariana* compared to other tortricid species to achieve good MD effect

Species	Dose (g/ha)	% trap catch reduction
Acleris comariana	14	99
Acleris comariana	1.4	97
Adoxophyes honmai	750	99
Adoxophyes orana	144-176	100
Cydia latiferreana	29	89
Cydia strobilella	12	99
Endopiza viteana	15-45	67-100
Endopiza viteana	80	98-99
Epiphyas postvittana	93	96
Epiphyas postvittana	5-95	48-94
Epiphyas postvittana	5-95	52-94
Grapholia molesta	37	53-96
Grapholia molesta	120	95-98
Rhopobota naevana	74	92

Summary

- Mating disruption seems to work efficiently for control of the strawberry tortrix
- Trap catch shutdown is achieved at much lower dose of pheromone compared to similar studies on other tortricid pests
- Treating whole crop fields is needed (will be done 2023-2024)
- The production cost of the pheromone has to be reduced
- A method for efficient dispersal of the pheromone in crop fields has to be developed

Questions?

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