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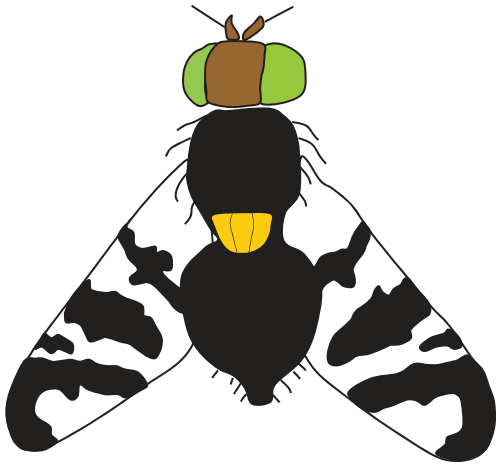
EXCELLENCE FOR SUSTAINABILITY

Pest Management of *Rhagoletis species*

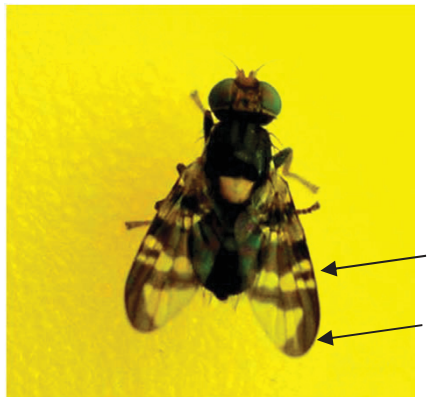


Claudia Daniel (claudia.daniel@fibl.org)

3rd European Workshop on Sea Buckthorn, Naantali (Fi), October 14-16 2014

Rhagoletis pest species in Europe

- *R. cerasi: European Cherry fruit fly*
- *R. cingulata / R. indifferens*: American cherry fruit flies



Rhagoletis pest species in Europe

- *R. completa :* walnut infesting
- *R. alternata:* on rose-hips

Rhagoletis

- Univoltine: one generation, long winter-diapause
- Oligophagous: few, perennial host plants →predictable in time and space but only available during a short period
- Presicion in seasonal synchronisation is important
- Emergence in spring is temperature dependent
- Pupal carryover for two or more years in case of failure of fruiting in one year
- Avoidance of larval competition by host marking

Biology of *Rhagoletis cerasi*

Overwintering: as pupae in soil directly under the tree, 10 month, well protected against antagonists
→ high winter mortality, parasitoids

Hatching: synchronized with host, temperatur dependent
→ forcasting models

Pre-oviposition period: 8-10 days, need to feed proteins (bird droppings, honeydew, bacterial colonies), no lack of food, no migration → food baits with protein hydrolysates

Mating: Resource-based mating system: males control the oviposition substrates, no long-range pheromone

Biology of *Rhagoletis cerasi*

Dispersal flight: low dispersal (<100m), only if host fruit are lacking → Netting for exclusion

Orientation: mainly visual: yellow surfaces and dark spheres of the size of host fruit
→ Yellow sticky traps

Oviposition: during warm and sunny weather, it takes a lot of effort; 200-400 eggs/female, host marking;
→ Host marking pheromones as repellents
→ Physical barriers

Biology of *Rhagoletis cerasi*

Larvae: eclosion after 6-10 days, 3 larval stages, 3-4 weeks; well protected; parasitation depends on host fruit size

Pupation: synchronized pupation; in the soil (2-3cm deep); very quickly within 2 hours after leaving the fruit
→ larvae leaving the fruit are very vulnerable to predators

Hosts: mainly Sweet Cherries (late ripening varieties),
→ not all varieties suffer the same losses
rarely Sour Cherries, Honeysuckle (*Lonicera xylosteum, L. tartarica*)

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Mortality

Mortality: **> 98% within one generation**

- **Conditions during overwintering (freezing, moisture)**
- **Destruction of cherries by fungal diseases or harvest**
- **Predators: (ants, birds, carabid and staphylinid beetles) during pupation or directly after hatching**
- **Parasitoids: 21 described species; efficacy of larval parasitods depend on fruit size;**
  mainly pupal parasitods (*Phygadeuon wiesmanni*):
  rate of parasitation 20-70%

Antagonists

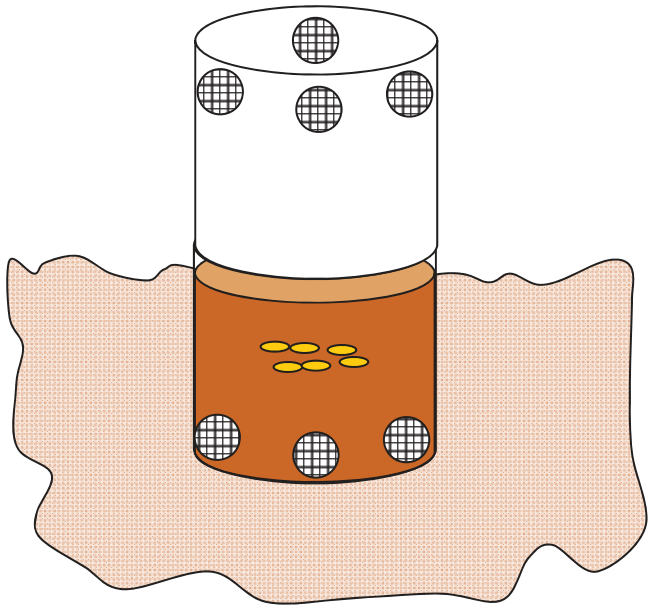
- Pathogens: different entomopathogenic fungi, registered biocontrol-products (*Beauveria bassiana*)
- Entomopathogenic nematodes: good laboratory results against *R. cerasi*, no field efficacy
- Viruses / Bacteria: no references on *Rhagoletis sp.*

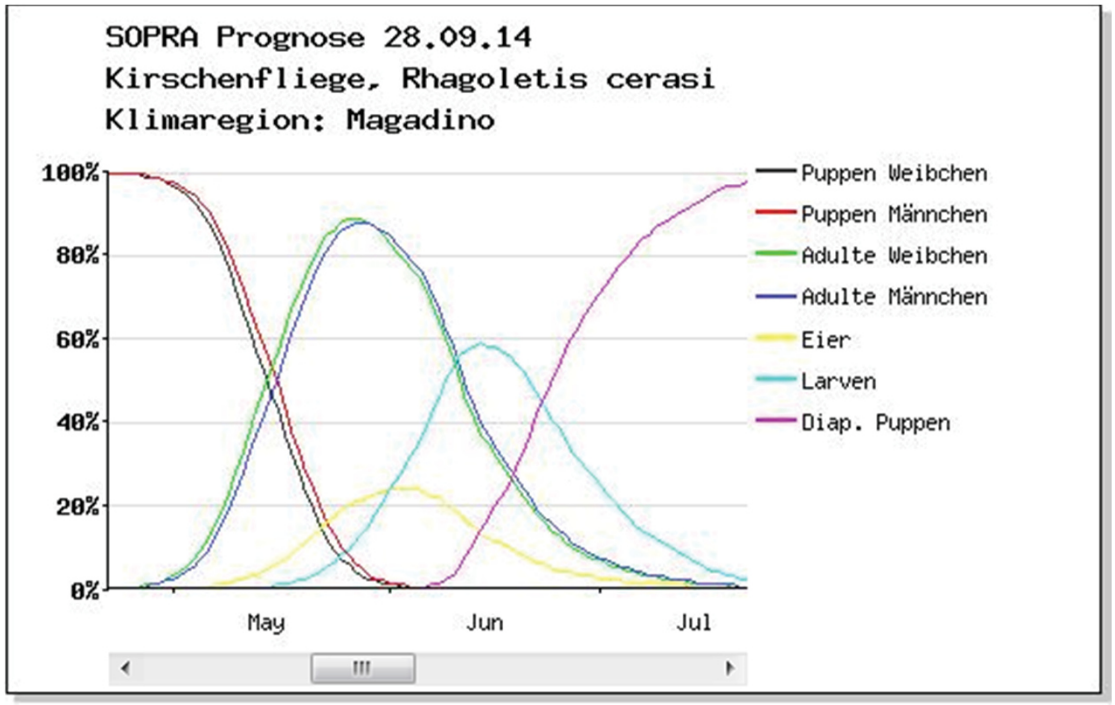
History of cherry fruit fly control

- 1900- 1935: before insecticide strategies
  - Early and complete harvest, early ripening varieties
  - Eradication of wild hosts
  - Soil treatments: mechanical and with oil
- 1905 – 1950: first insecticides against adult flies
  - Lead arsenate, rotenone, pyrethrum with food baits
  - DDT
- 1950-2000: Organophosphorous insecticides
  - Against larvae: Dimethoate and Fenthion
- 1960 – 1990: Research on biotechnical approaches
  - Sticky traps, host marking pheromones, sterile males
- 1990 – 2010: Biocontrol: nematodes, fungi, baits

Monitoring: adult flies

- Yellow sticky traps
- Forecasting models
- Depots of pupae





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Monitoring: Fruit infestation

- **Salt water test:**
  - 100 randomly picked cherries
  - Crushed until the pits are separated from the pulp
  - A saturated salt solution (350 g salt per liter water) is added
  - Floating larvae can be counted after 10 min

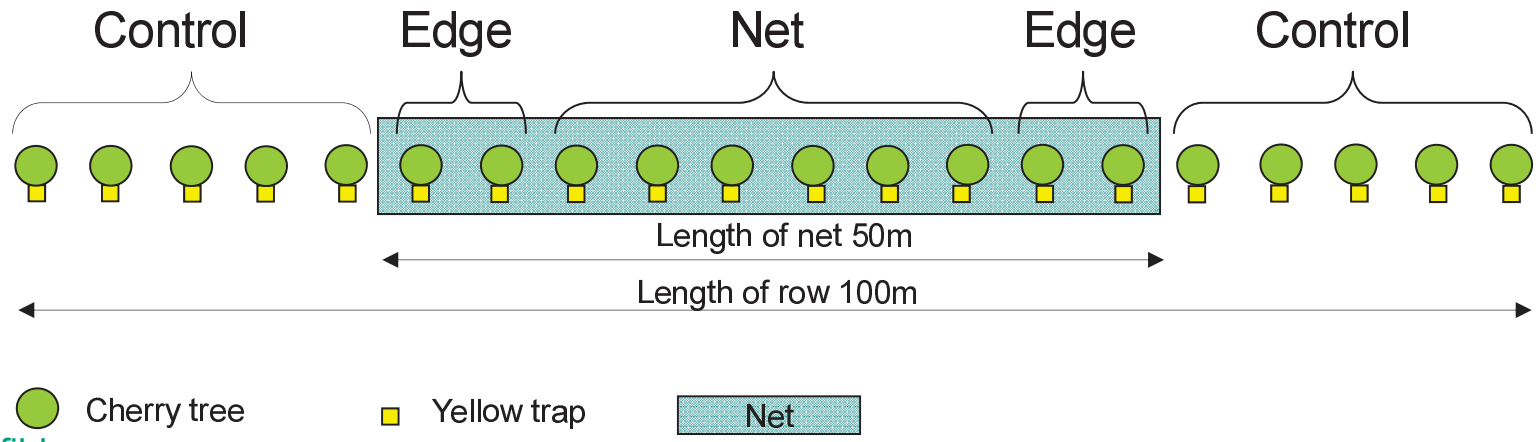
Prevention

- Early ripening cherry varieties
- Early and complete harvest of fruit
- Varieties suitable for mechanical harvest
- Removal of infested fruits
- Uncutted grass under tree canopies:
  higher plant cover→lower soil temperatures→ delaid fly emergence for up to 10 days
- Removal of Lonicera and unharvested cherry trees in close vincinity
- Poultry or sheep keeping under cherry trees

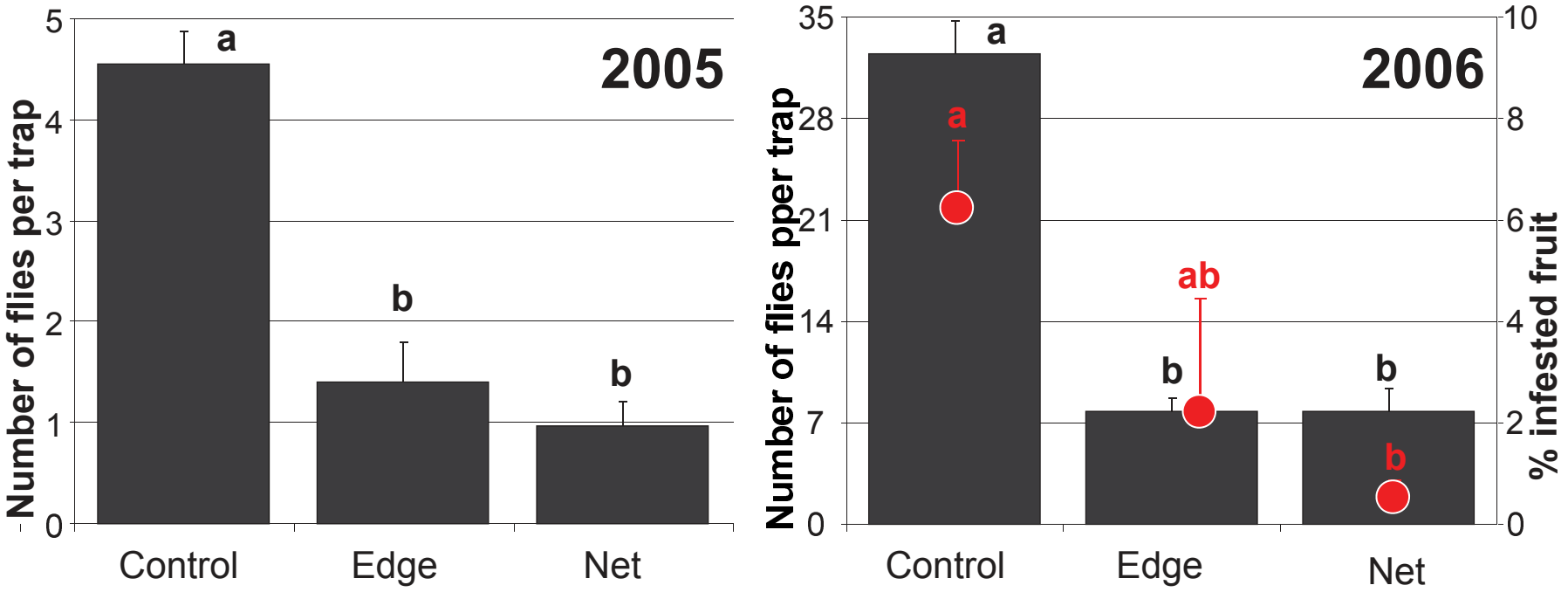
Control – use of nets

- Mesh size 1.3 mm
- Installation before beginning of flight period
- Only applicable on small trees
- Increase in aphids due to exclusion of antagonists
- Only economic if trees are already covered

Soil covering



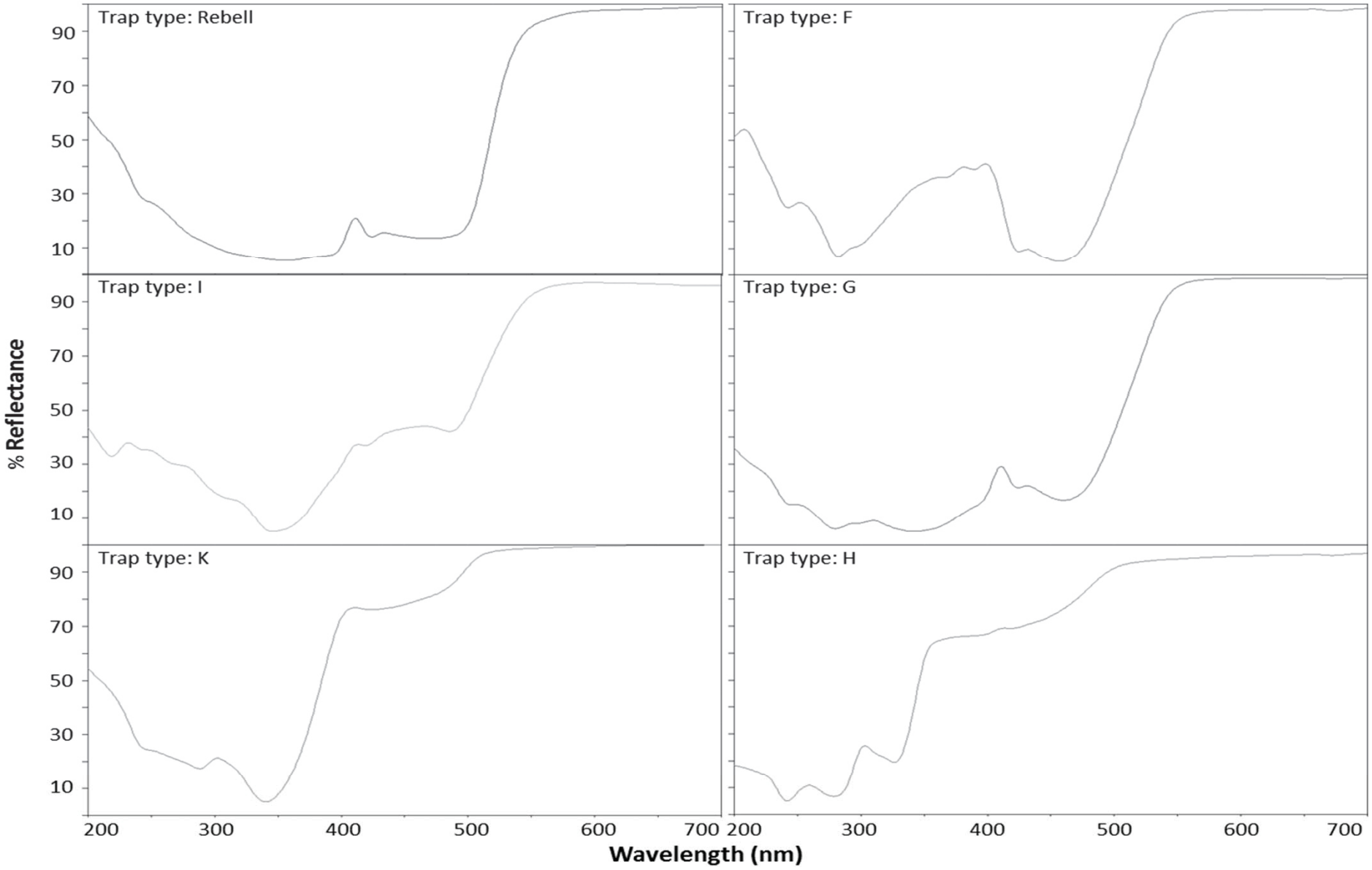
Soil covering



- Good efficacy: Reduction of fruit infestation by 90%.
- Flies do not disperse much.
- High labour input, obstruction of tractor lanes.
- Soil treatments are a possibility to control the flies.
- For house gardens and high trees.

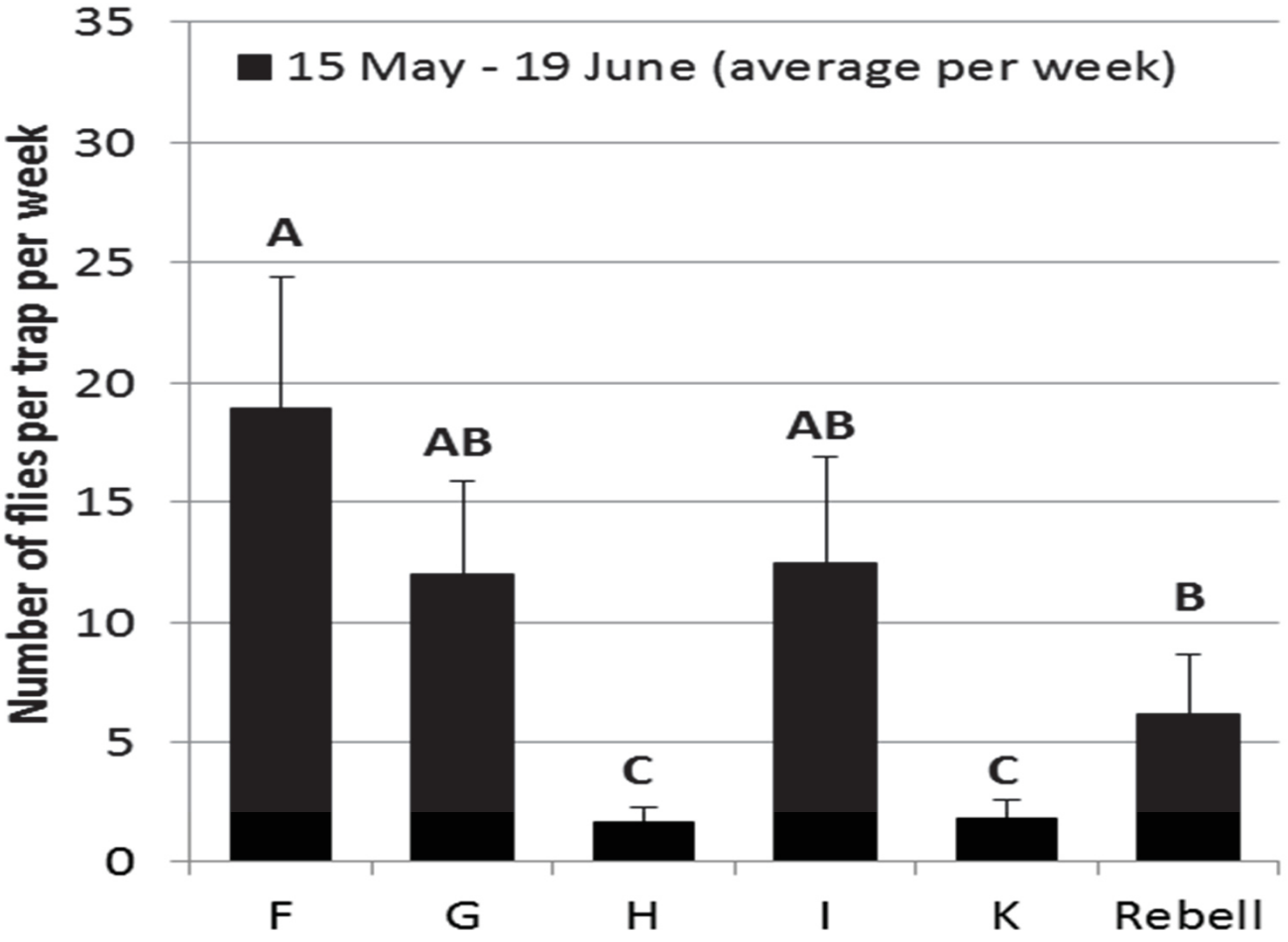
Mass-trapping

- Flies are attracted to yellow, but not any yellow:
- *Reflectance:*
  - major peak at 485 to 500 nm (yellow green region)
  - sharp increase of reflectance in the 500 to 520 nm region
  - secondary peak at 365 nm (ultraviolet region)


Trap type: Rebell
Trap type: F
Trap type: I
Trap type: G
Trap type: K
Trap type: H
% Reflectance
Wavelength (nm)
90
70
50
30
10
200
300
400
500
600
700


F
G
H
I
K
L

Mass-trapping: trap types

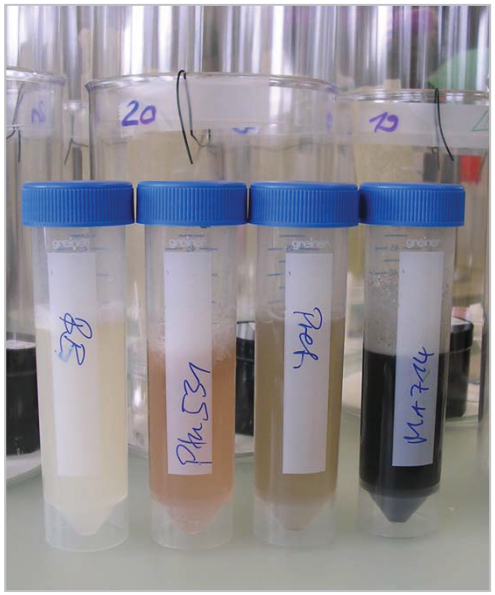


Mass-trapping: Baits

- Flies need proteins for gonad maturing
- Flies are attracted by smell of decaying proteins:
  - Ammonia releasing substances (ammonium acetate)
  - Trimethylamine, Diaminobutane
  - Yeast hydrolysate, chicken dung, urine
- 17 different baits were tested, 7 experiments, 3 years
- Baits could duplicate catches
- For good efficacy: 1 trap per m of canopy diameter

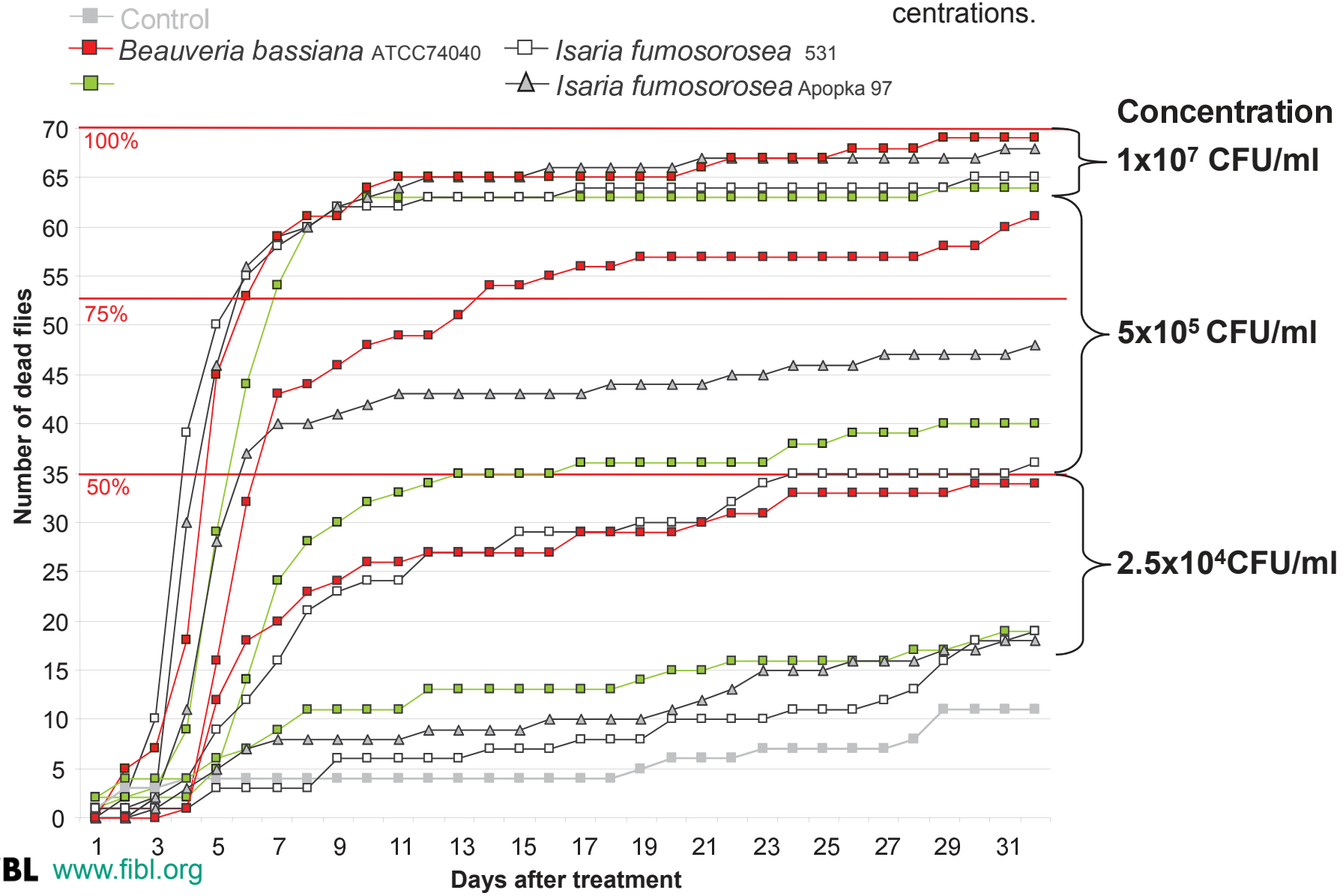
  → High costs, high labour input, many by-catches
- Not economic.

Entomopathogenic fungi: Lab experiments



Entomopathogenic fungi: Lab

Adult flies (1-5 days old; 9 females, 5 males, 5 replicates) were treated with a conidia suspension in 3 concentrations.



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Entomopathogenic fungi: Lab conclusions

- Adult flies are highly susceptible.
- Fungus isolates differed considerably in virulence.
- Effect on fecundity mainly attributed to reduced life-span of females.
- Most efficient at low concentrations: *Beauveria bassiana* ATCC 74040.
- Infestation of flies by soil treatments is depending on soil moisture.
- Susceptibility of larvae was very low; efficacy under field conditions is assumed to be negligible.

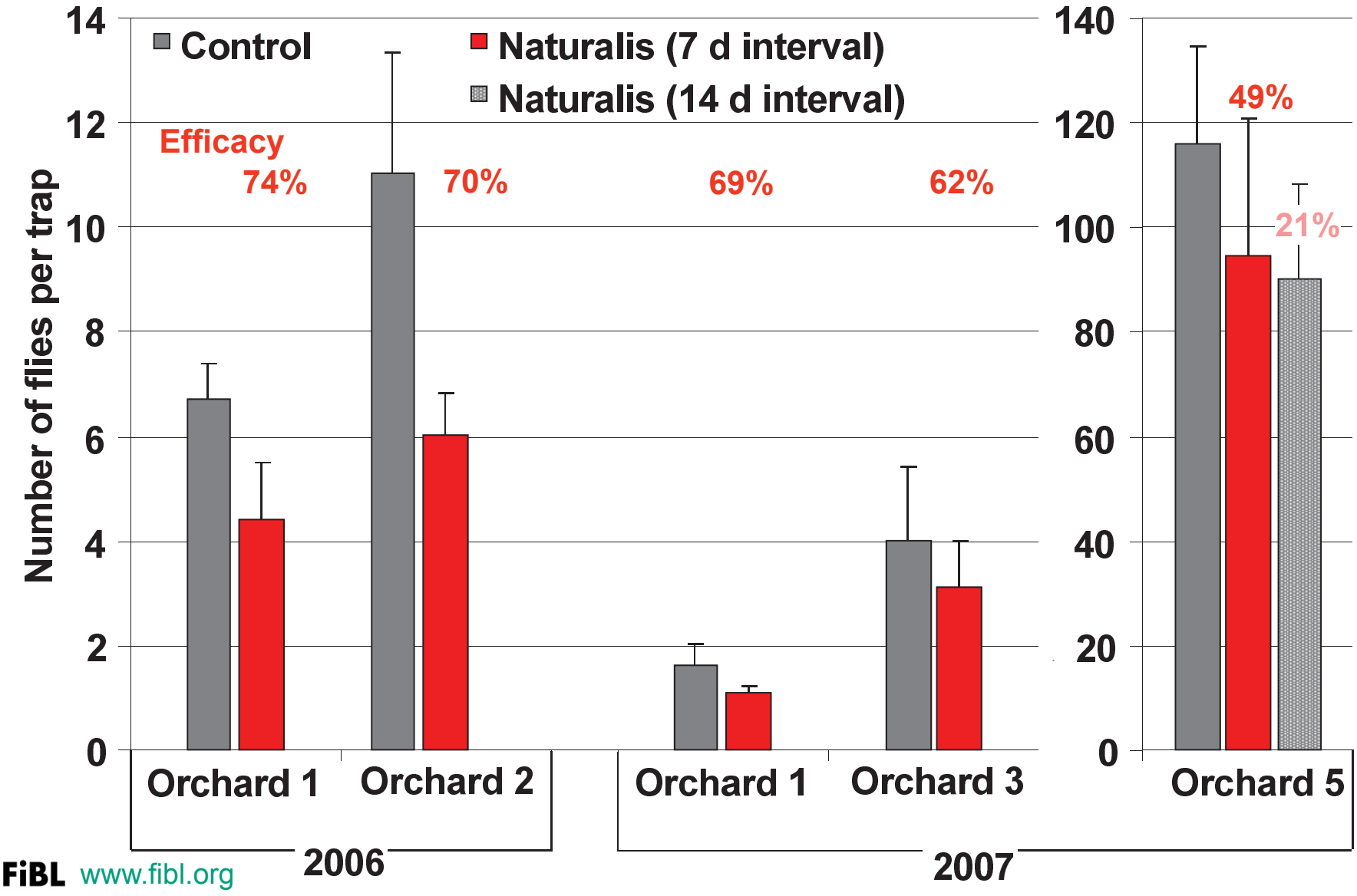
Entomopathogenic fungi: Field strategies

- **Attract-and-Kill**
  - → ***Traps and baits***: 17 different baits were tested in 7 experiments in 3 years: low response of flies to baits.
- **Soil treatments**
  - → ***Soil coverage*** with nets promising results
  - → ***Entomopathogenic fungi***:
    in 2007 (rainy weather): oviposition rate reduced by 90%,
    in 2008 (dry weather): no effect.
- **Foliar applications in tree canopy**

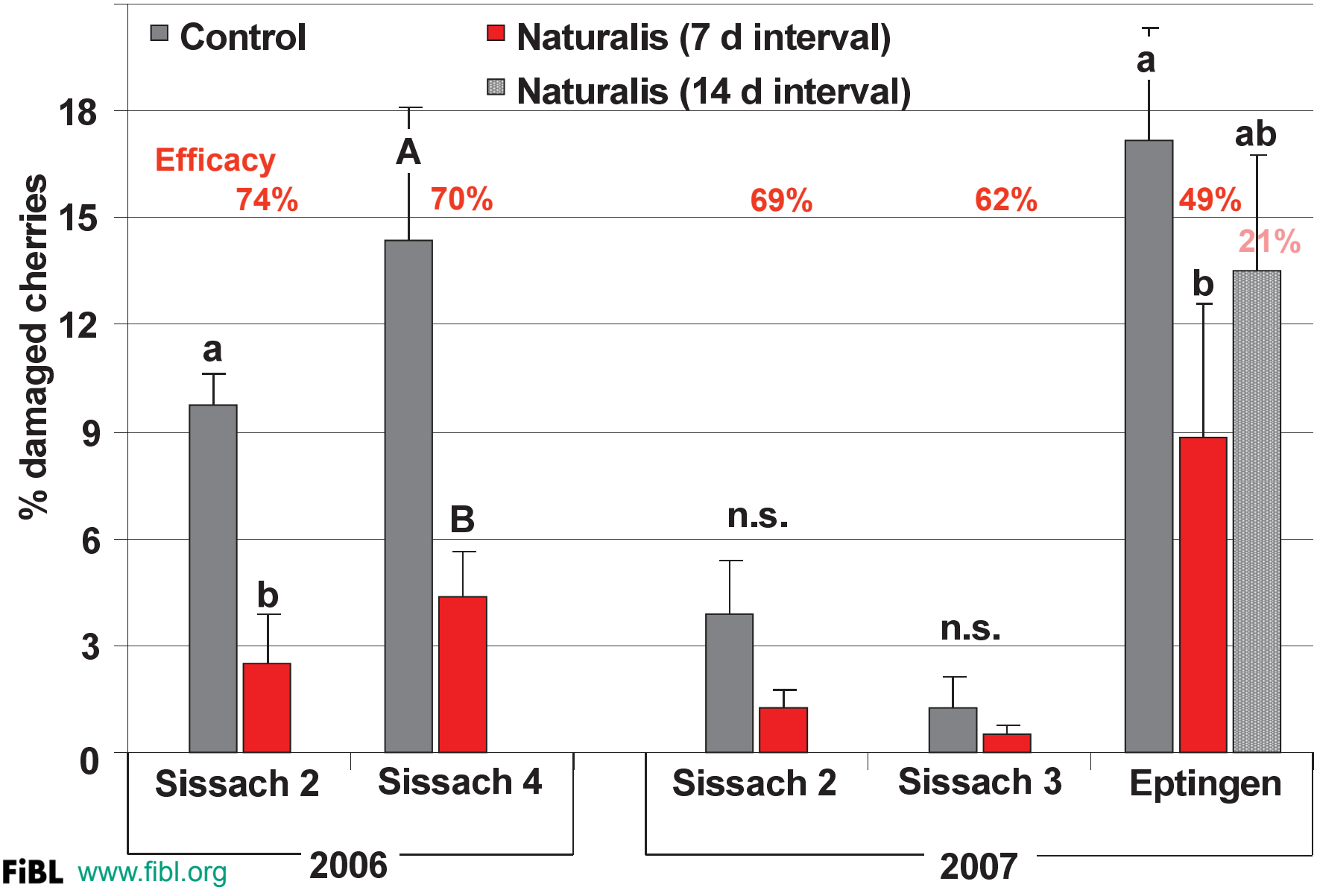
Entomopathogenic fungi: Foliar applications

- Naturalis-L (*B. bassiana*)
- Concentration: 250ml Naturalis-L / 100l
- 1st treatment: within 5d after beginning of flight period
- Treatments in 7 day intervalls
- Last treatment: 7-14 d before harvest
- Completely randomized block design
- 5 experiments in 2 years
- Monitoring of flight intensity: one yellow sticky trap per tree
- Evaluation of infestation level: fruit samples at harvest

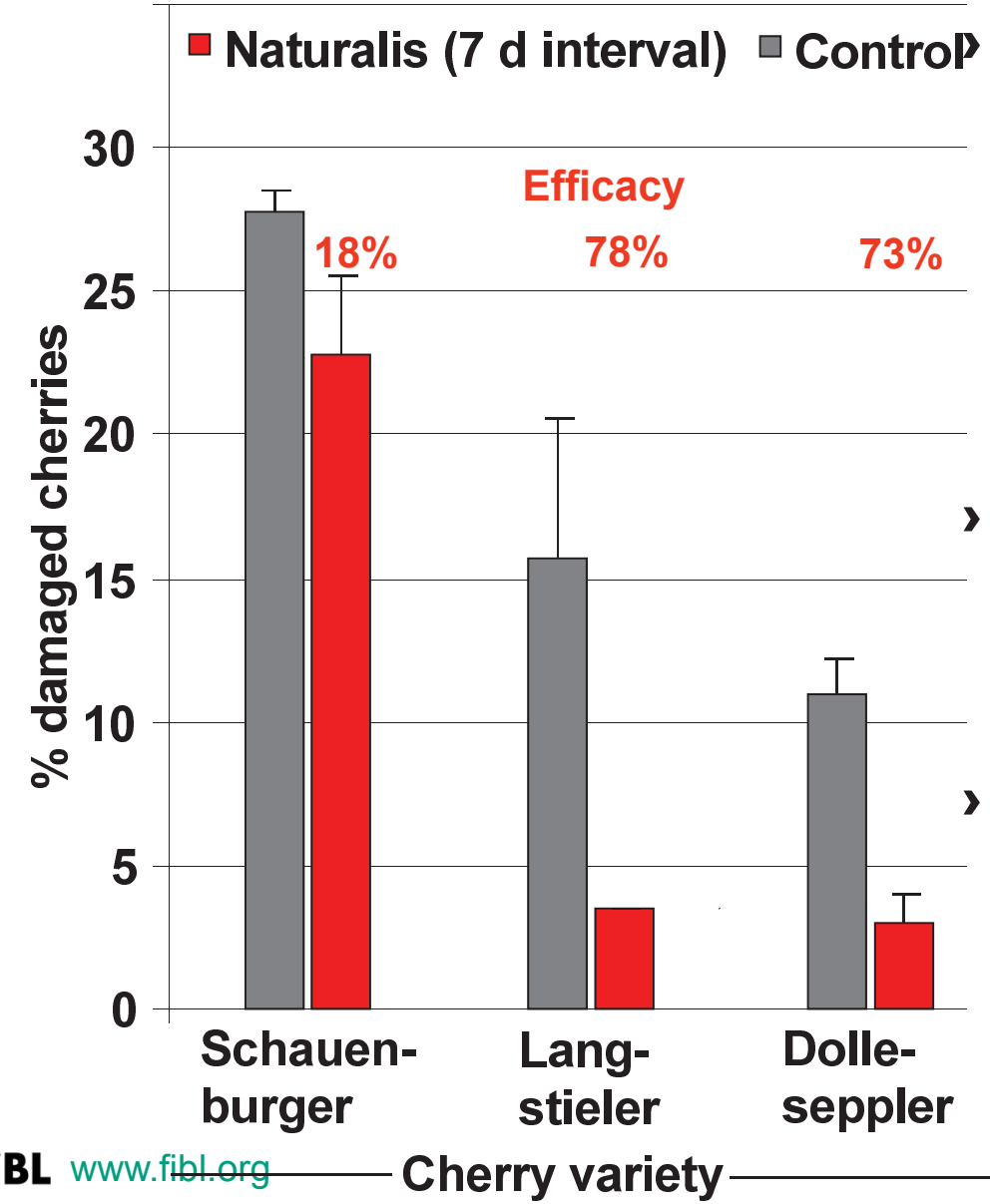
Entomopathogenic fungi: Foliar applications



Foliar applications: Fruit infestation



Entomopathogenic fungi:Foliar applications



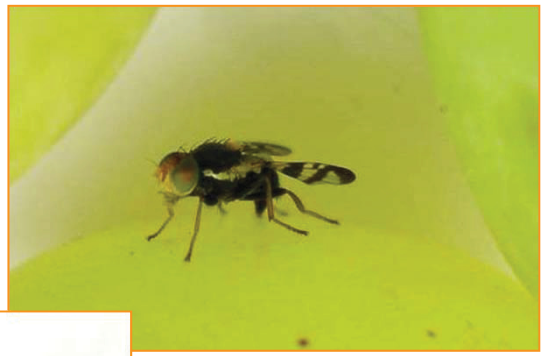
- Larval stages in treated cherries:
  - Variety Schauenburger: 50% in L_1 or L_2 stage
  - Variety Dollesepplerr: 4% in L_1 or L_2 stage
- Time to harvest:
  - Variety Schauenburger: 14d
  - Variety Langstieler: 7d
- Negative correlation:
  - Efficacy and days until harvest (7 to 14 days)
  - $R^2 = 0.57$; $p = 0.05$

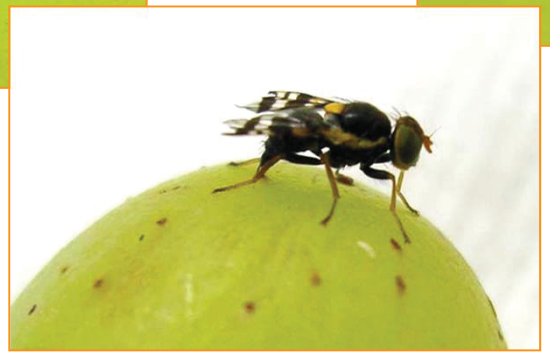
Entomopathogenic fungi: Conclusions

- Experiments in 2 years in 4 different orchards.
- Infestation of flies under field conditions is possible.
- Conidia on cherry leaves remain active for 7 days: repeated applications are necessary.
- Application regime must be adapted to cherry variety.
  - First treatment: 7 days after beginning of flight period.
  - Treatments in 7d intervals.
  - Last application: 7d before harvest.
- Reduction of fruit infestation by 60-70% (not always sufficient).
- Naturalis-L registered for this indication.
- Unsuitable for high trees.

Physical barriers

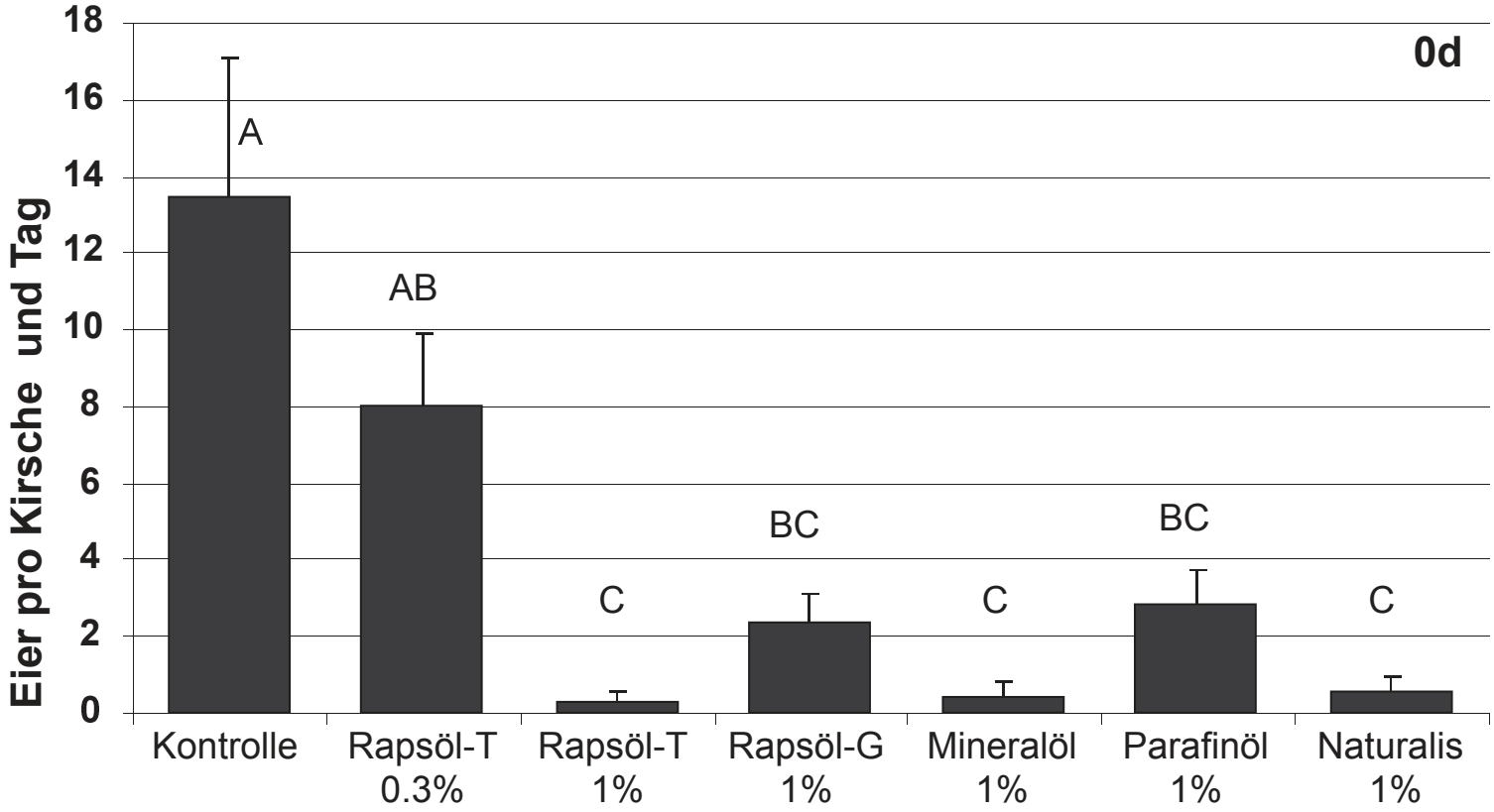
- Penetrating fruit skin is challenging for flies.
- Physical barrieres (oil products, Kaolin clay): reduced grip/adhesion of tarsae .
- Clay products are not an option for cherry because of residue





Physical barriers: oil products

- Single branches of a cherry tree were treated
- 0, 3, 6 and 9 days after treatement, cherries were exposed to flies in the laboratory



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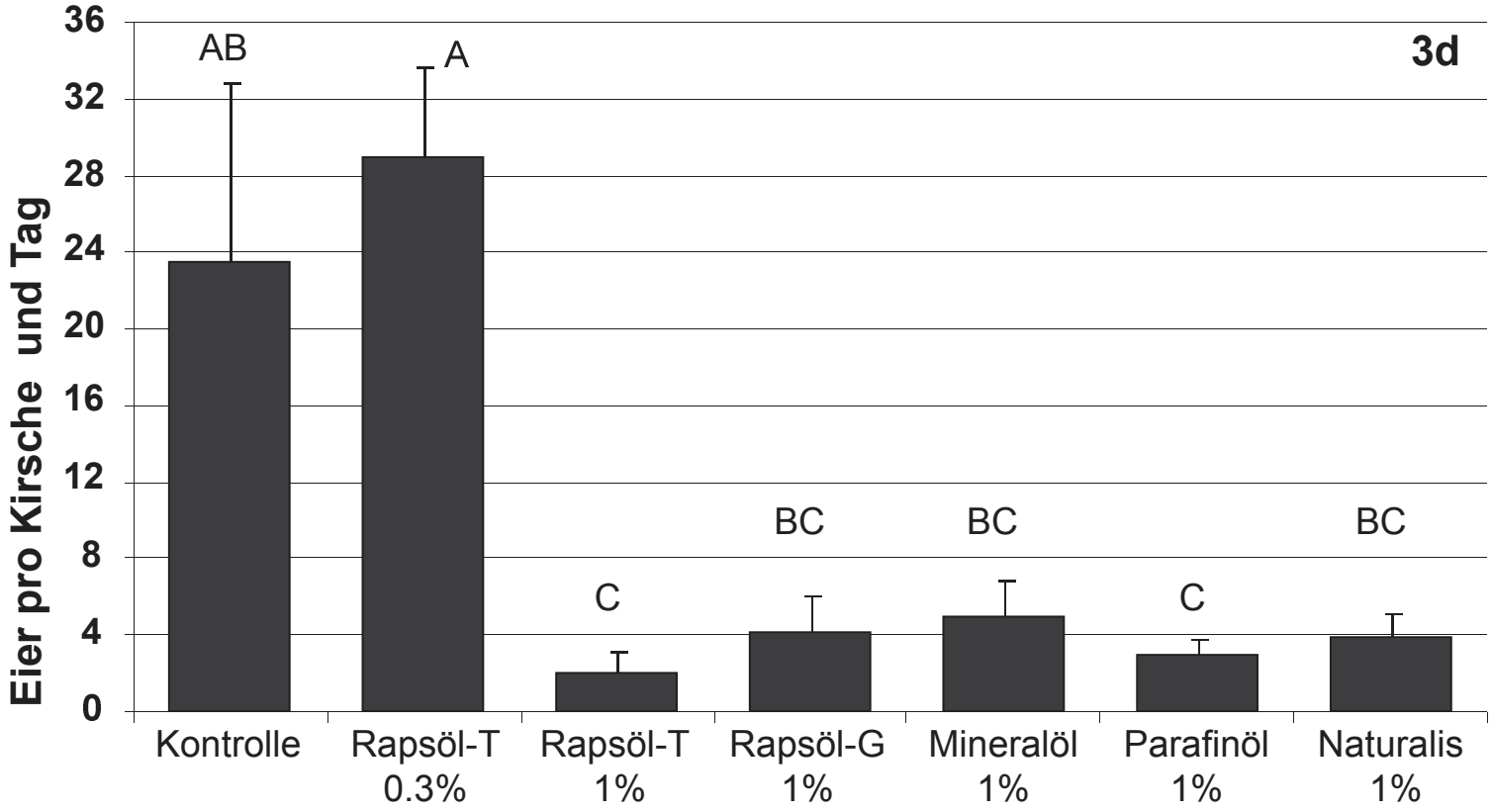

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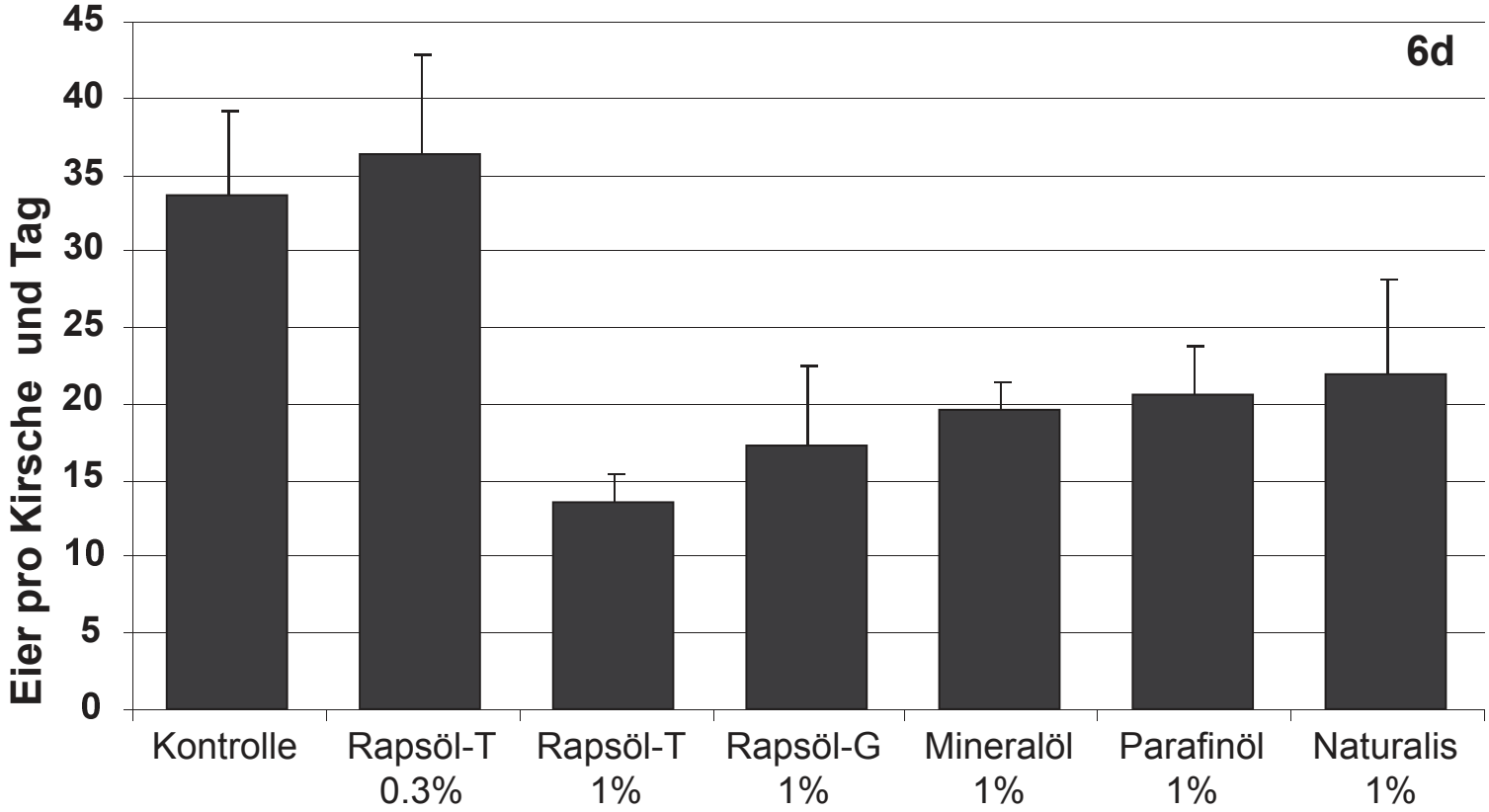

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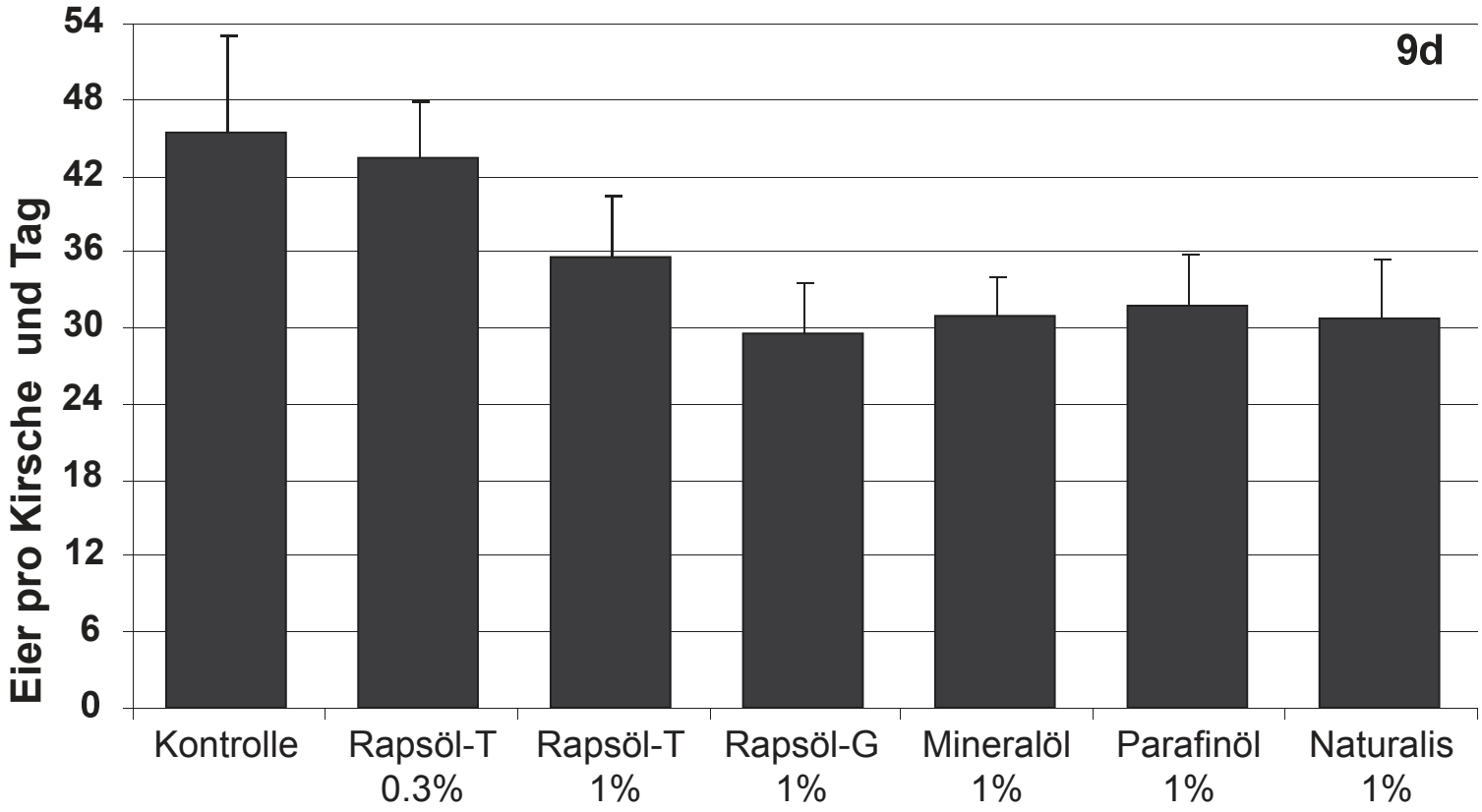


Physical barriers: Conclusions

- Oil products are promising, but improvend product formulations are needed
- Kaolin clay (Surround®WP) not suitable for cherry, but it might be an option for hawthorn

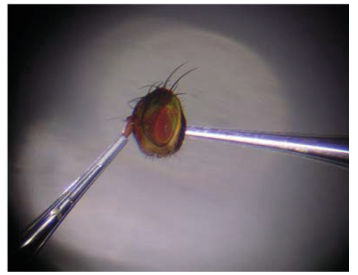
Control - Insecticides

- Dimethoate (no longer registered in most EU countries)
- Neonicotinoids
- Spinosad
- Bait formulations of Spinosad: GF120 or CombiProtec
- Efficacy depend on climate

Recommendation for control

- Monitoring of flight period with yellow traps.
- Monitoring of fruit damage (salt water test).
- Dwarf-tree orchard:
  - Net covering
  - Application of Naturalis-L (Beauveria) (in regions with moist climate)
  - Application of Spinosad-bait formulation (in regions with dry climate)
- Semi-dwarf trees:
  - Soil covering with netting
  - Application of Spinosad-bait or Naturalis-L
- High standard trees:
  - Soil covering with netting
- Single trees, home gardens
  - Mass trapping: yellow traps+baits

Research opportunities



- Pupal parasitoid *Phygadeuon wiesmanni*
  - High natural parasitation rates of 2nd generation
  - Lab-rearing and mass-release seems promising
  - So far, only monitoring of parasitoid presence
- Sexual pheromone
  - Not yet fully identified
  - Interaction between host volatiles & pheromone
- Host marking pheromone
  - Described in 1970ies
  - Too expensive for conventional production;
  - Synthetic product: Not suitable for organic
- Wolbachia induced cytoplasmatic incompatibility
- Formulation of oil products

› Thank you for you attention!